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**Pinchuk et al.**

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(54) **STRETCH VALVE BALLOON CATHETER  
AND METHODS FOR PRODUCING AND  
USING SAME**

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continuation-in-part of application No. 12/943,453,  
filed on Nov. 10, 2010, now Pat. No. 8,382,708, and a

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(51) **Int. Cl.**

**A61M 25/10** (2013.01)  
**A61M 25/00** (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ..... **A61M 25/1018** (2013.01); **A61B 5/205**  
(2013.01); **A61M 25/0017** (2013.01); **A61M**

**25/04** (2013.01); **A61M 2025/1093** (2013.01);  
**A61M 25/10185** (2013.11)

(58) **Field of Classification Search**

CPC ..... **A61M 25/0017**; **A61M 25/1018**;  
**A61M 25/10185**; **A61M 25/10184**; **A61M**  
**25/04**

See application file for complete search history.

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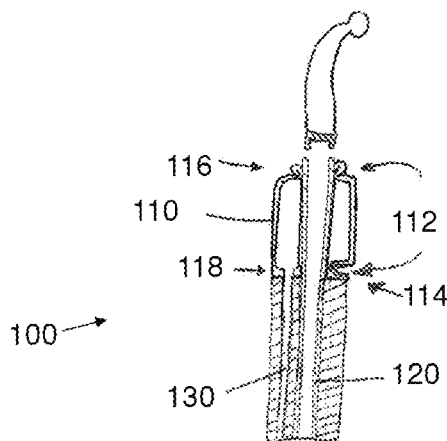
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Gregory L. Mayback

(57) **ABSTRACT**

A safety catheter includes a flexible, multi-lumen shaft having an outer diameter, a distal tip, a proximal catheter end with a drain end and a proximal inflation end. The multi-lumen shaft defines a drain lumen, a distal hollow balloon portion, at least one inflation lumen, and a drainage port. A hollow stretch valve is coaxially disposed in the drainage lumen, has a fixed portion within the drainage lumen just proximal of an increased stretching portion, and prevents fluid from passing through the drainage port in a steady state. The stretch valve has a sliding portion slidably disposed within the drainage lumen such that, in a stretched state when the proximal catheter end is stretched, the sliding portion slides within the drainage lumen to permit fluid to pass through the balloon drainage port and/or inner wall of the catheter.

**19 Claims, 19 Drawing Sheets**



**Related U.S. Application Data**

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filed on Dec. 7, 2012, now Pat. No. 8,591,497.

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(51) **Int. Cl.**

*A61M 25/04* (2006.01)

*A61B 5/20* (2006.01)

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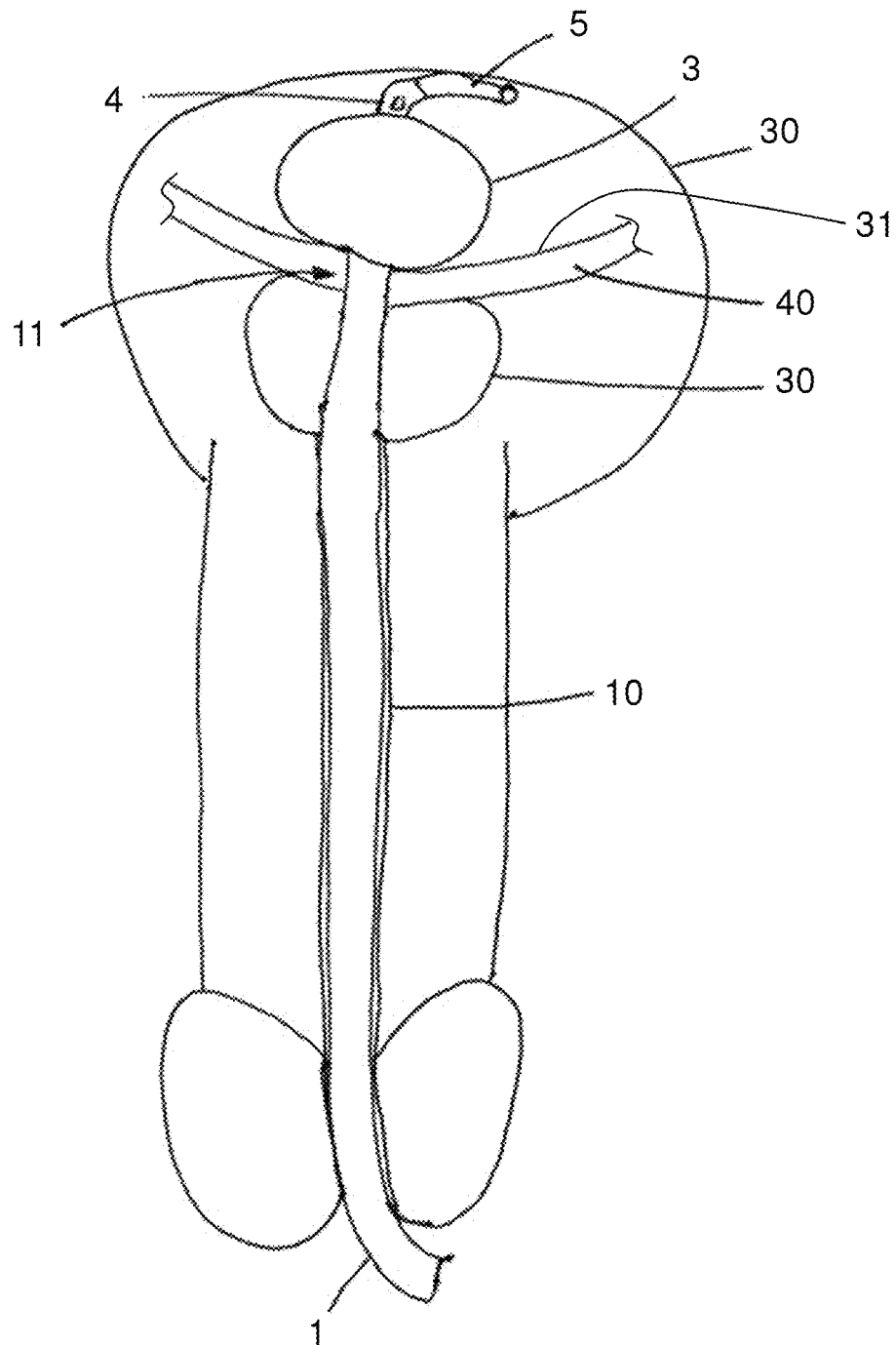
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FIG. 1  
Prior Art



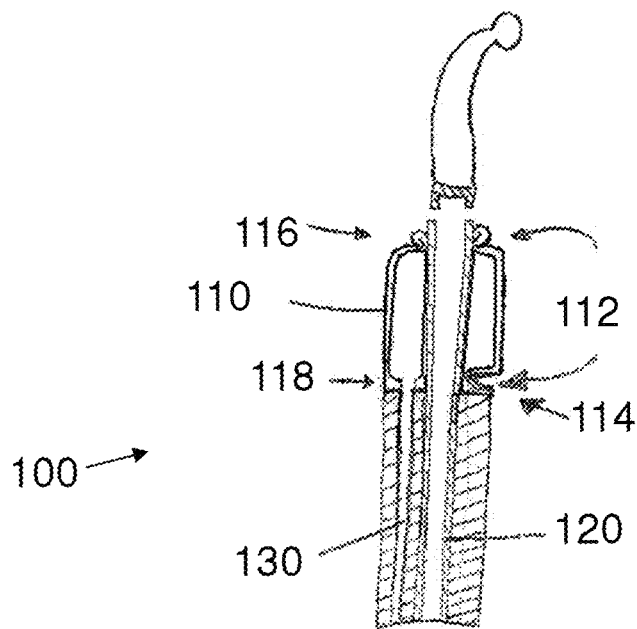


FIG. 2

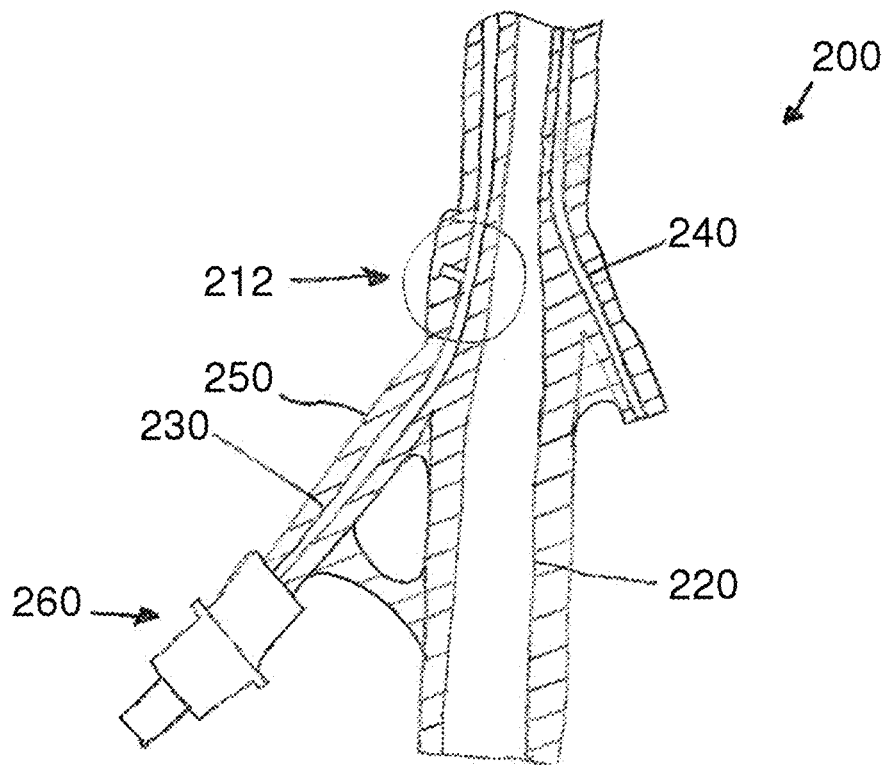


FIG. 3

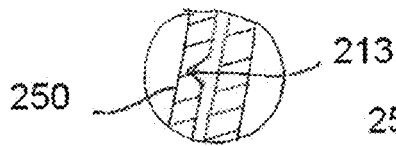


FIG. 4



FIG. 5

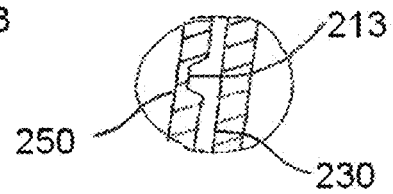


FIG. 6

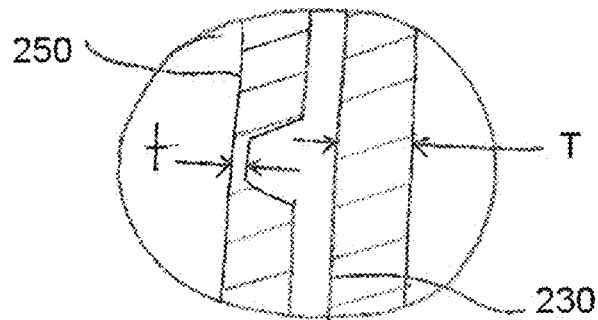


FIG. 7

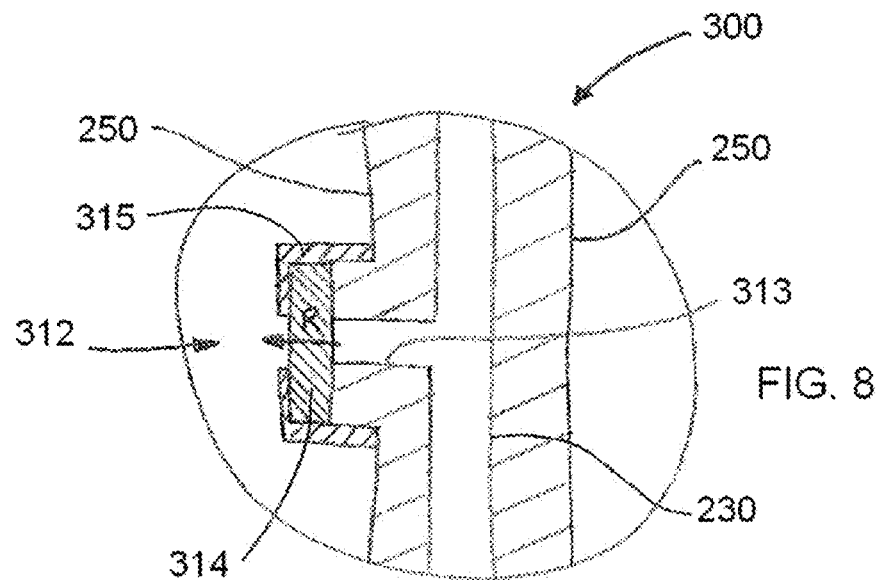


FIG. 8

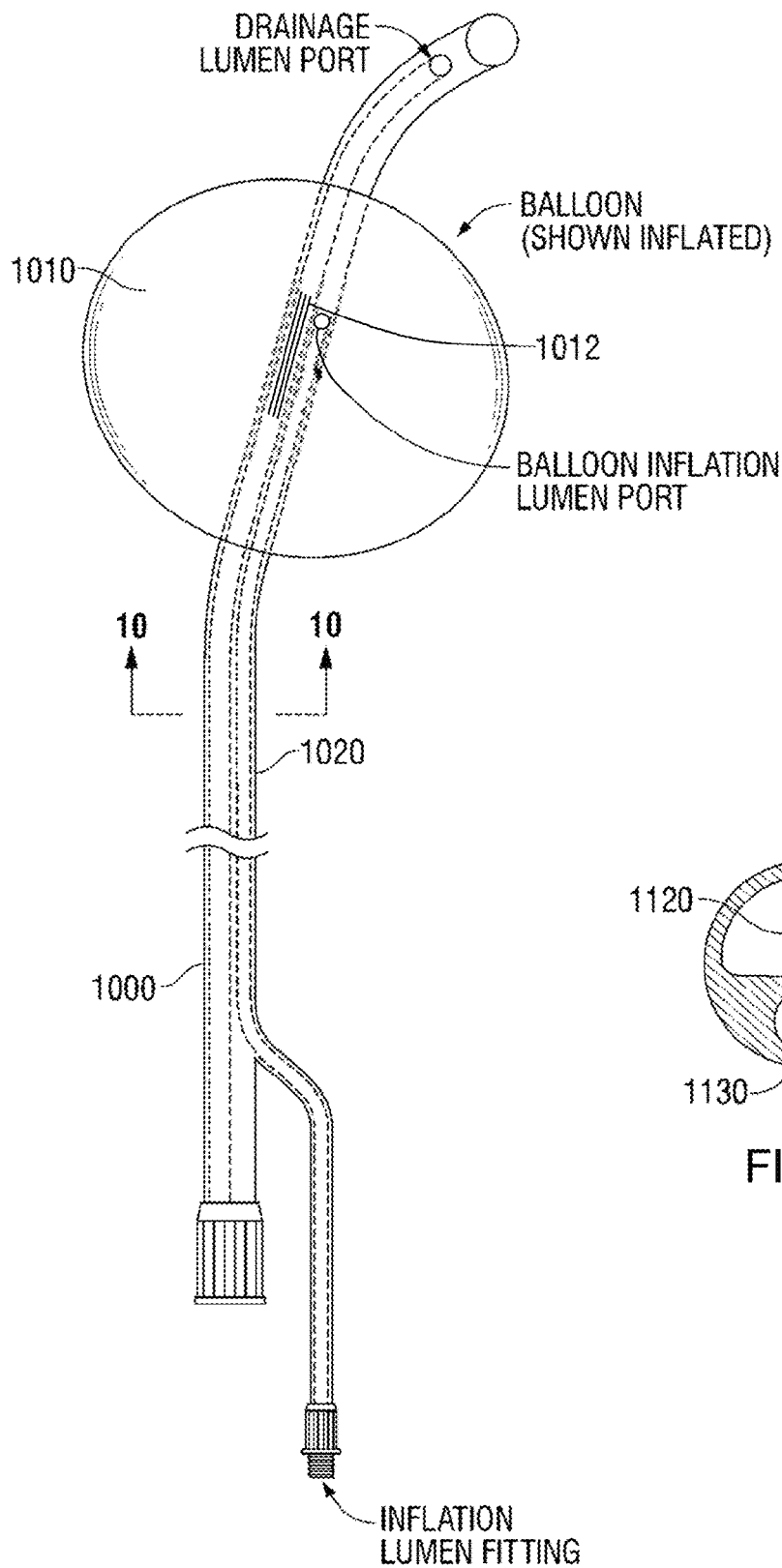


FIG. 9

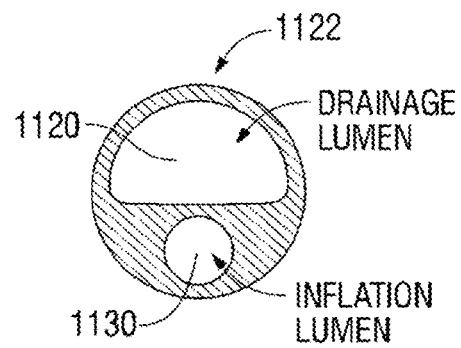


FIG. 10

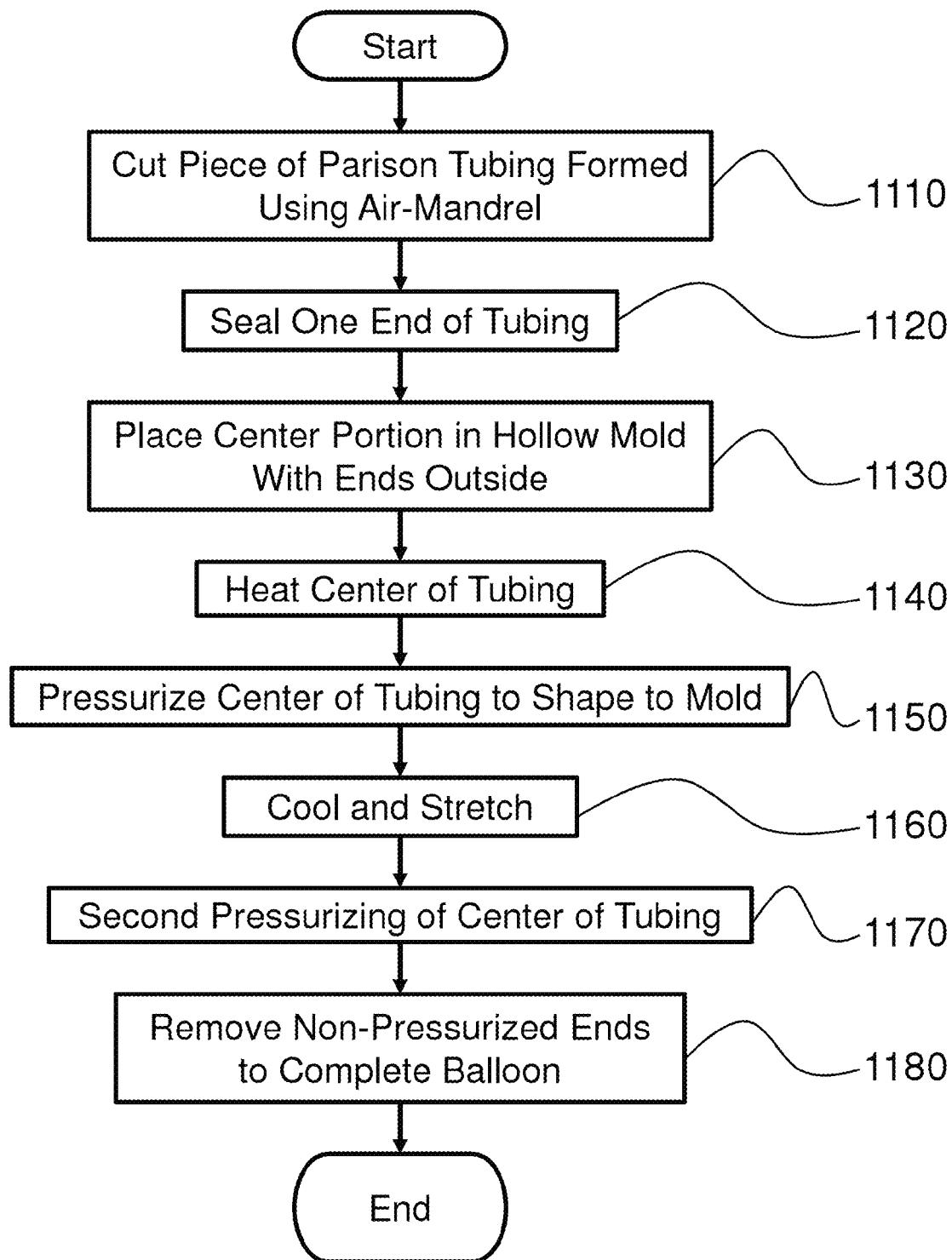


FIG. 11

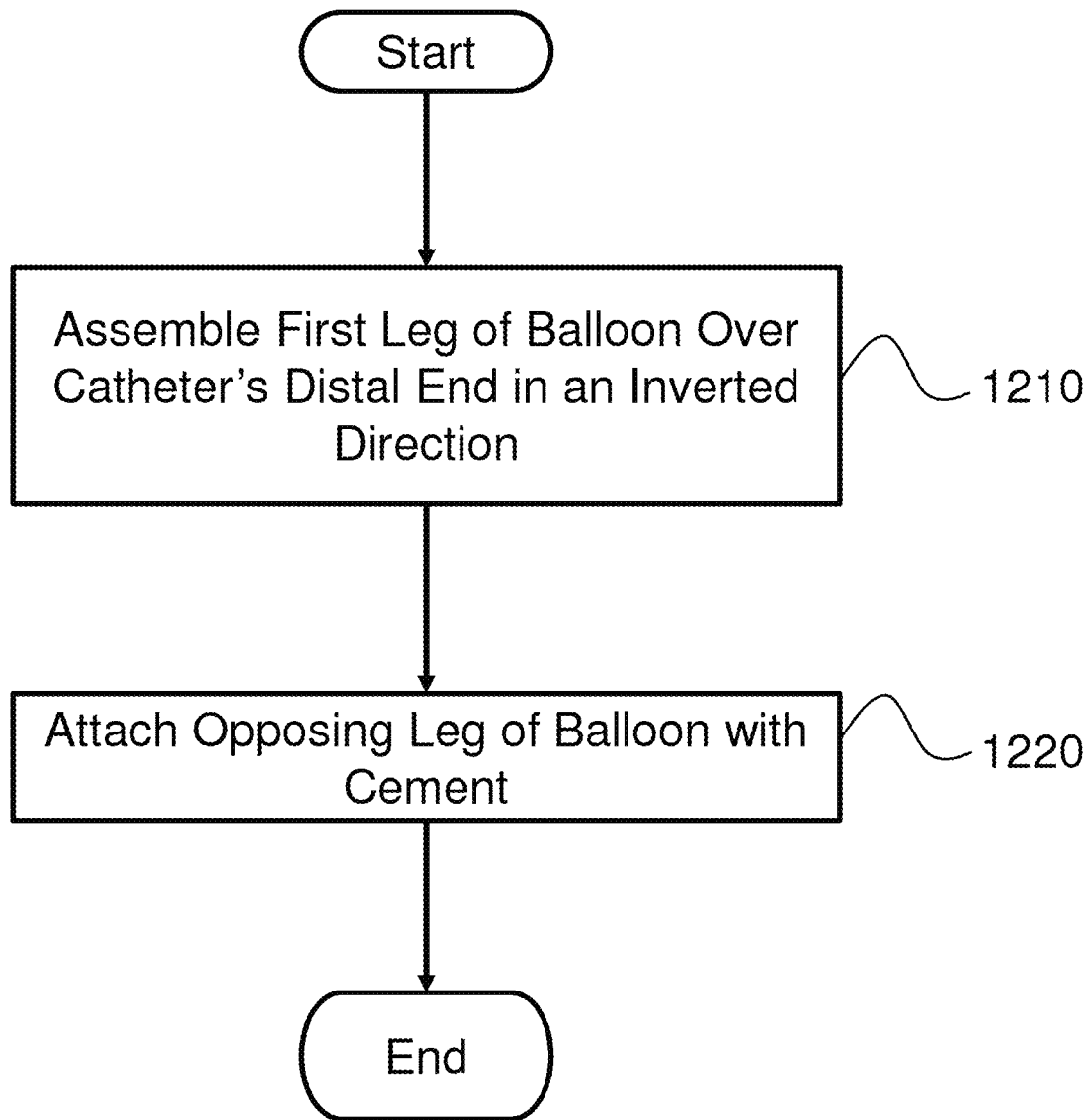


FIG. 12



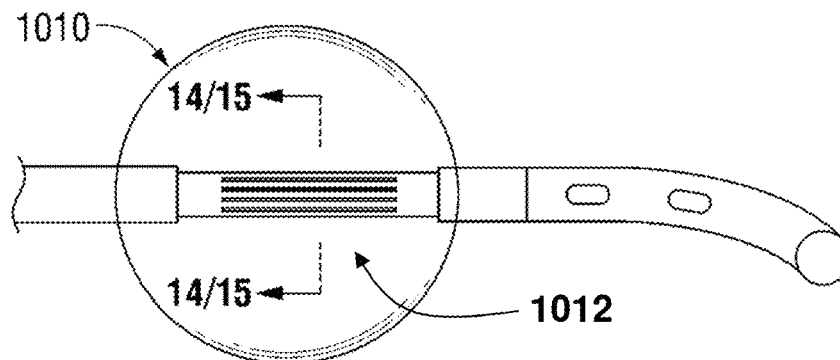


FIG. 13

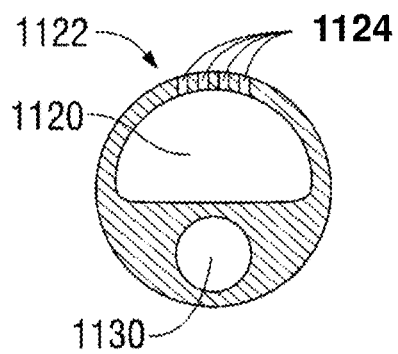


FIG. 14

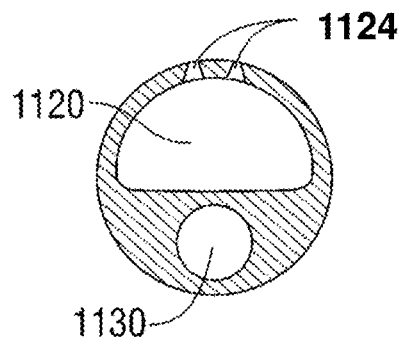


FIG. 15

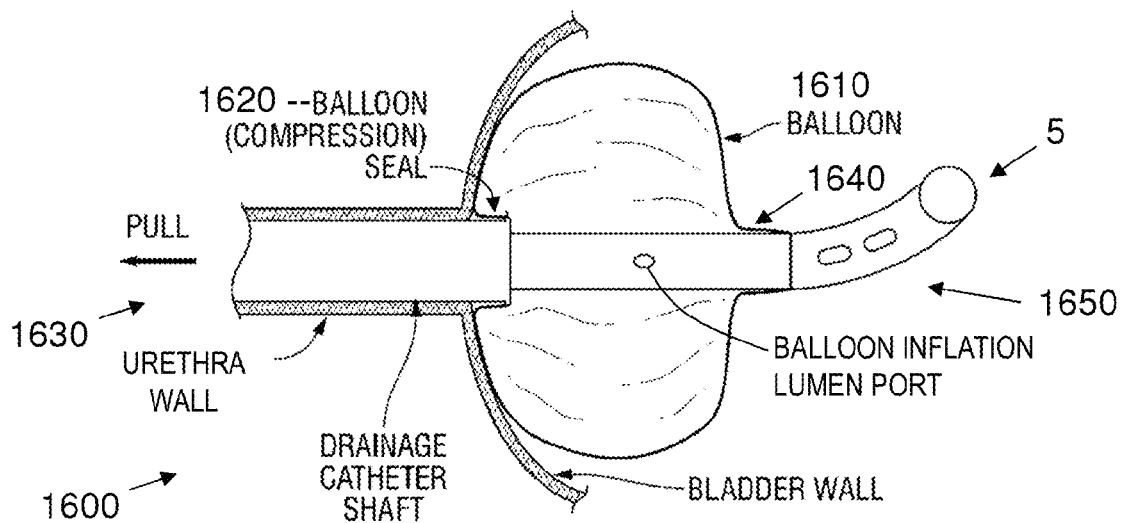


FIG. 16

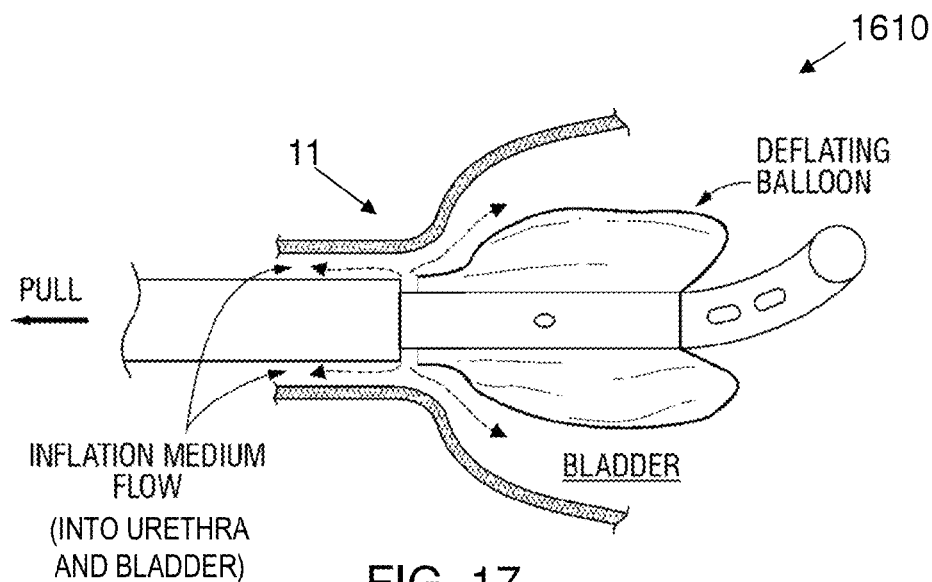


FIG. 17

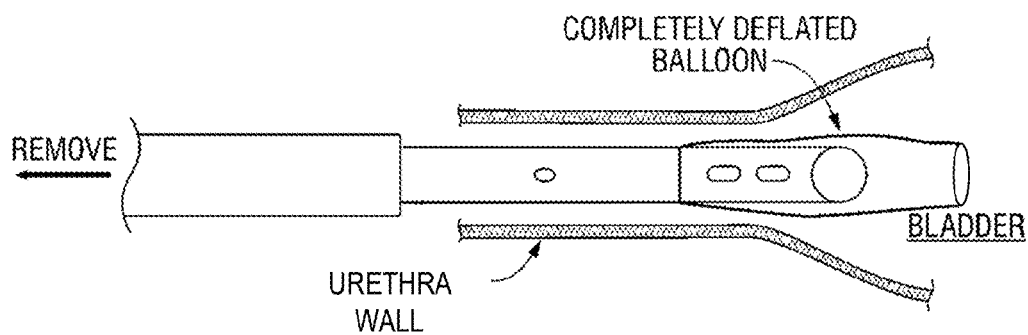
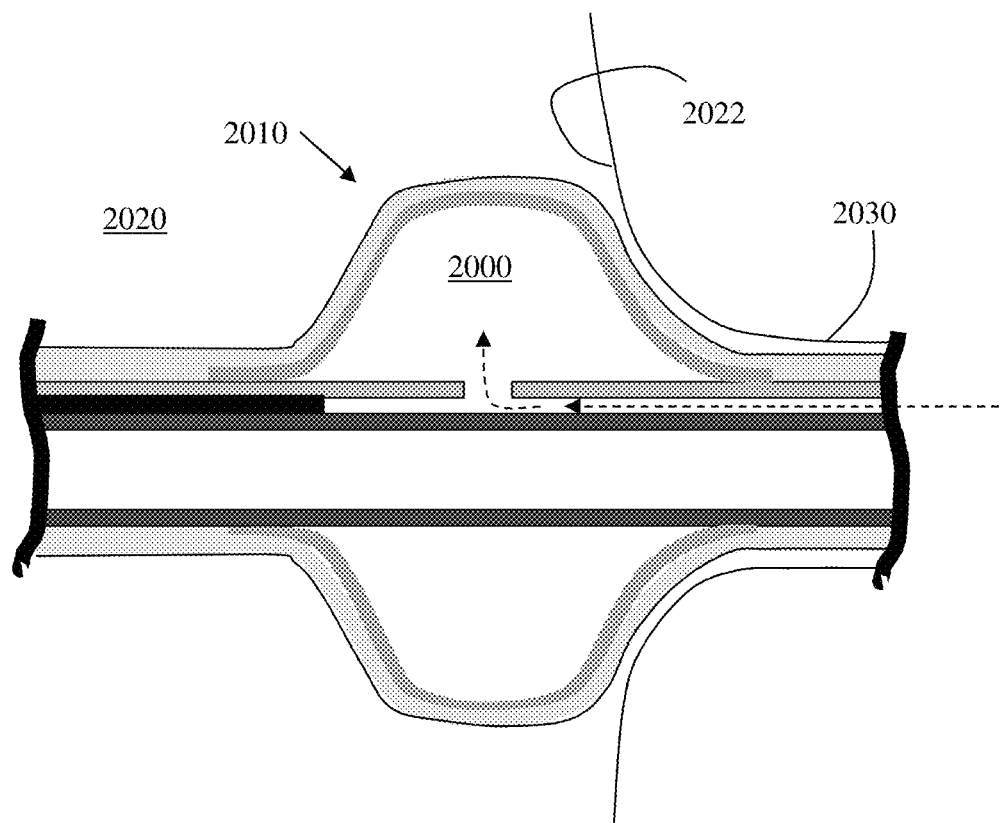
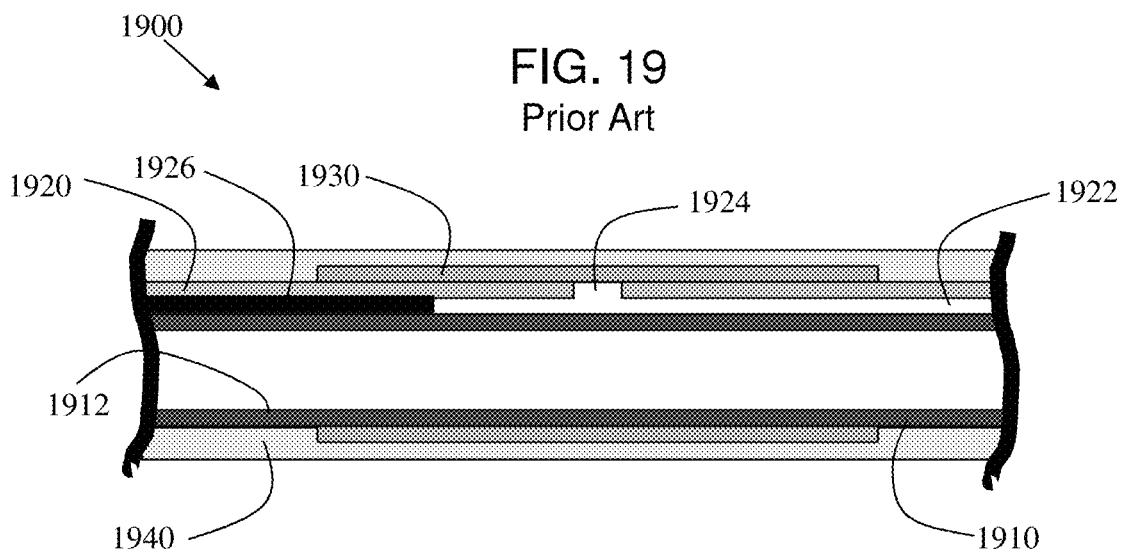
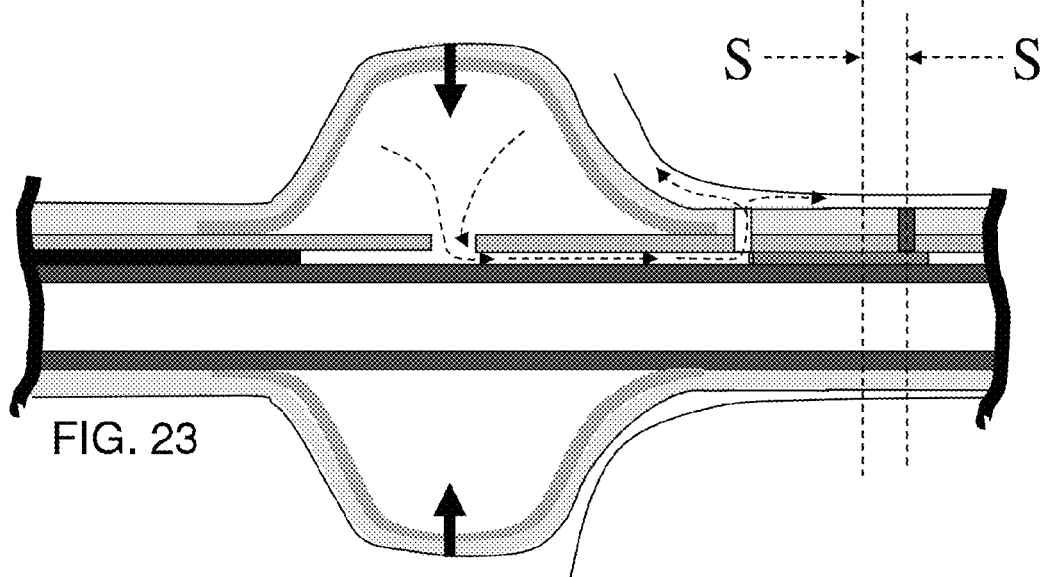
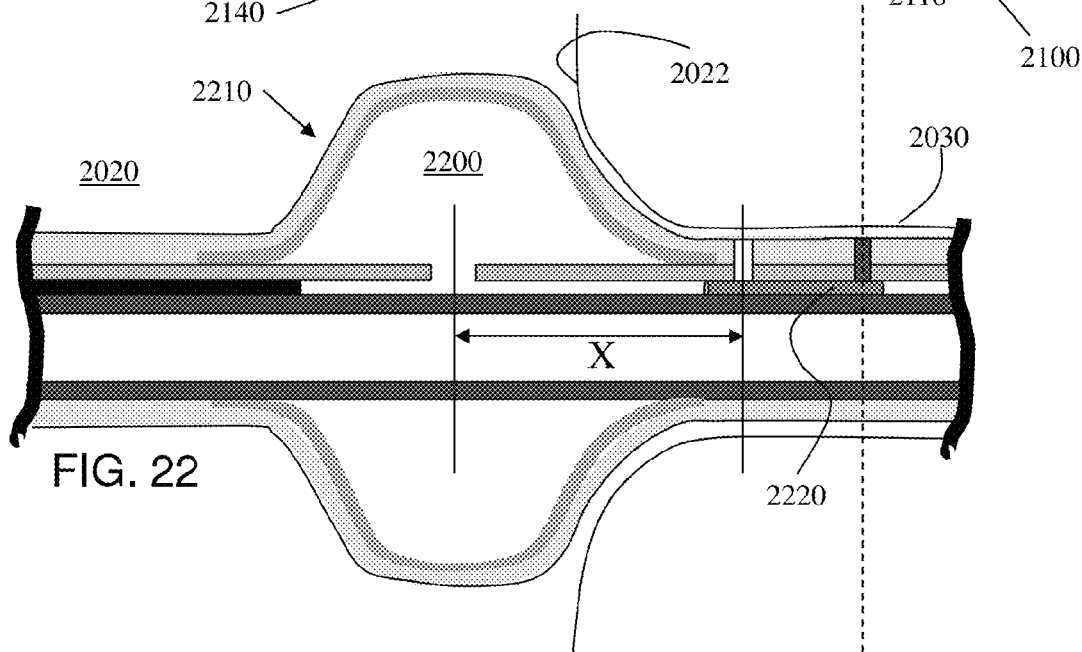
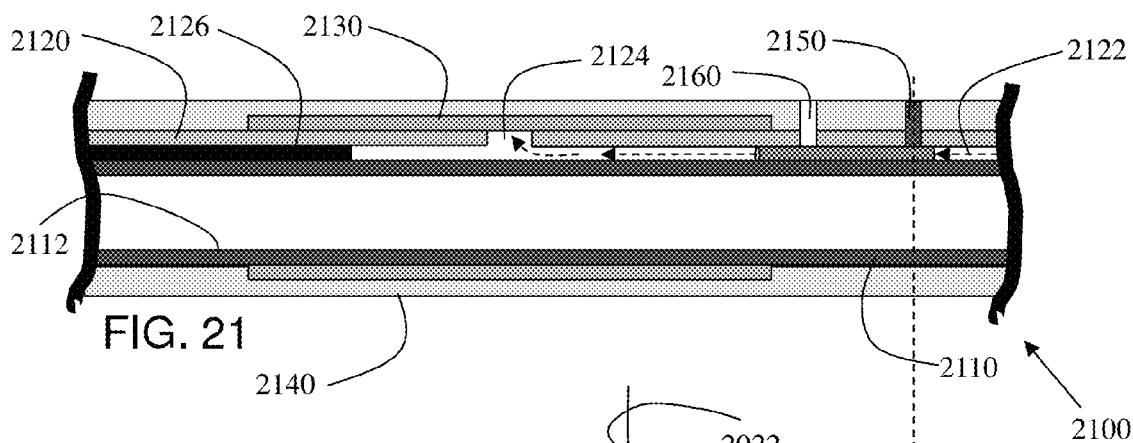
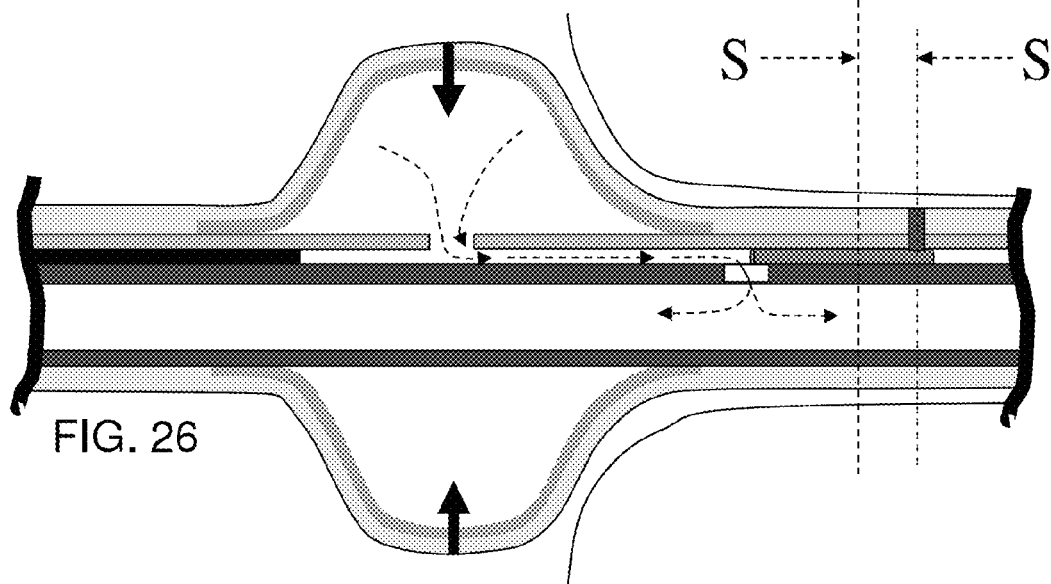
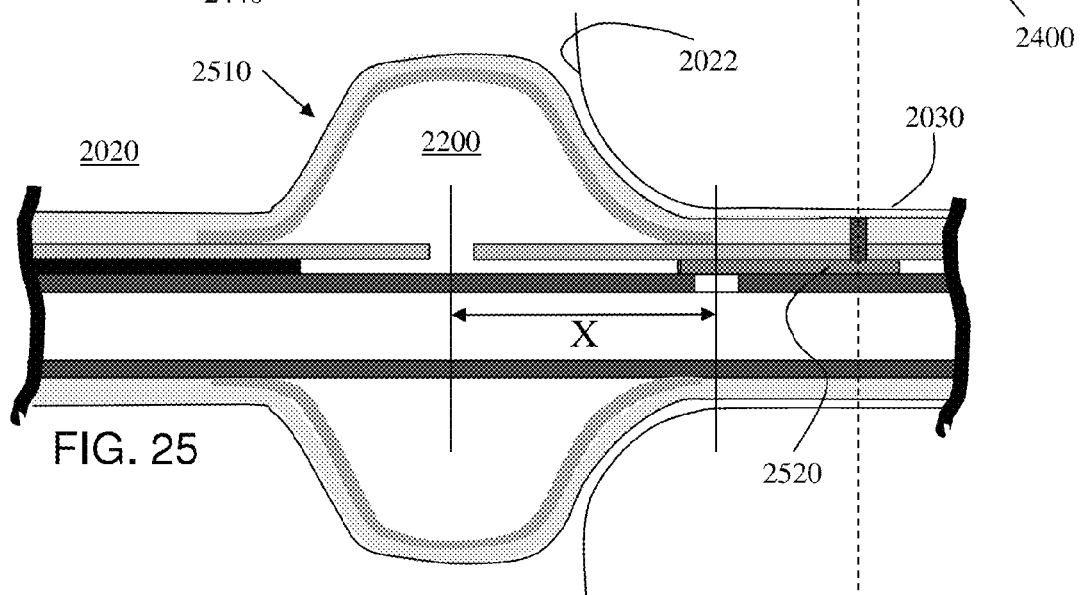
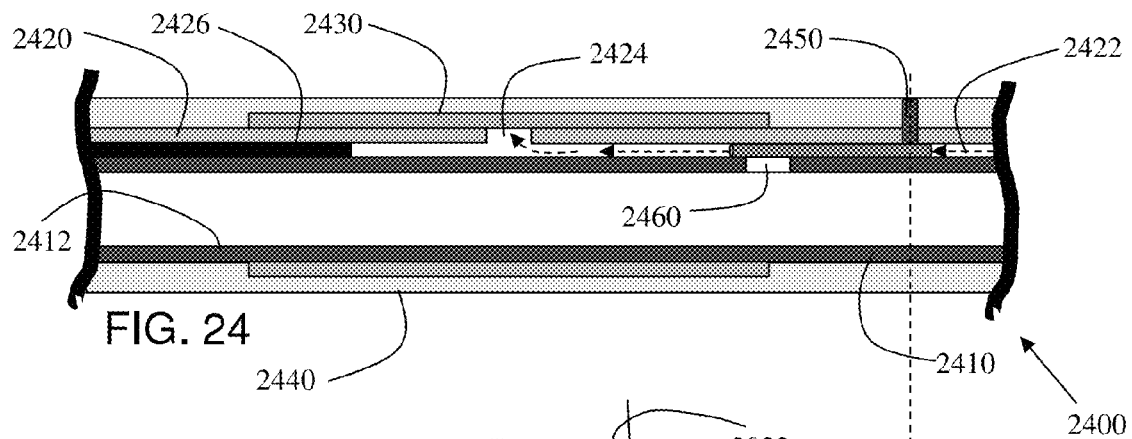


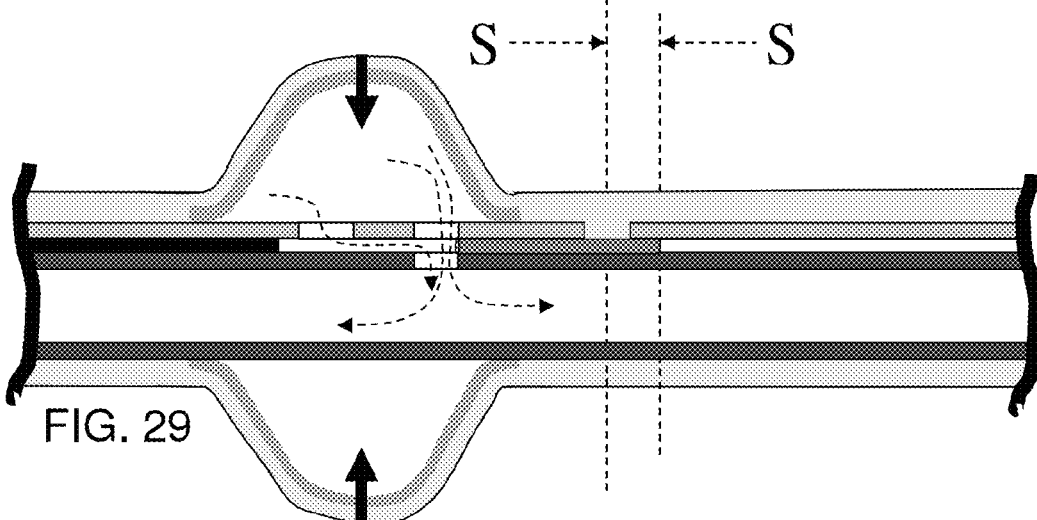
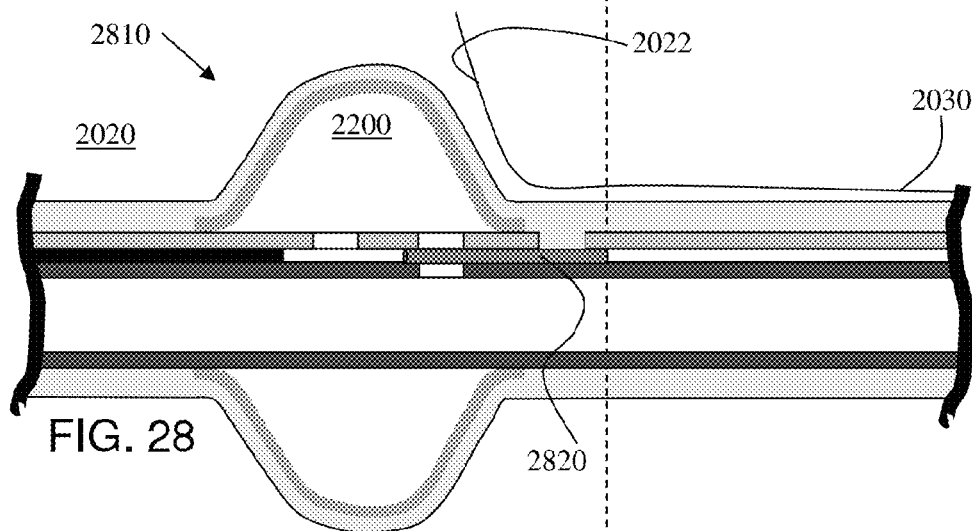
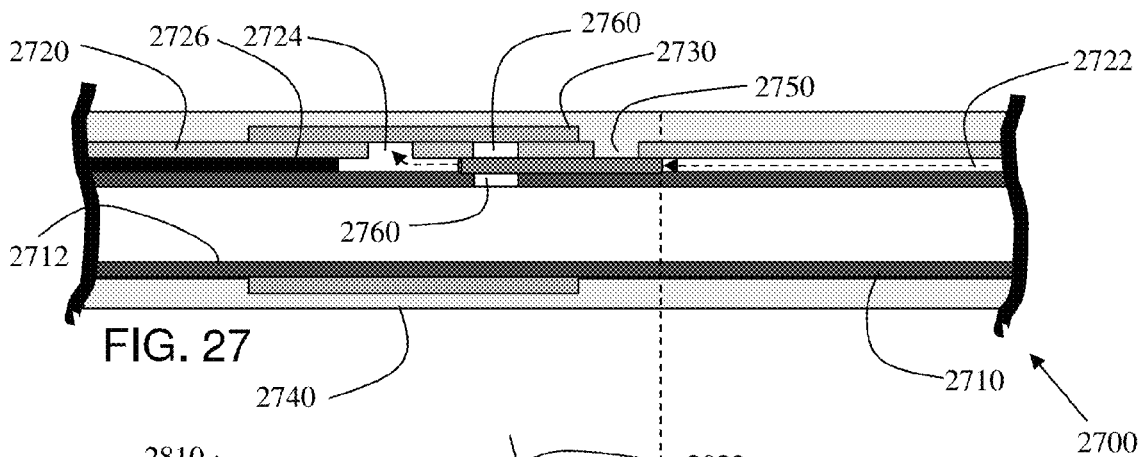
FIG. 18



**FIG. 20**  
Prior Art







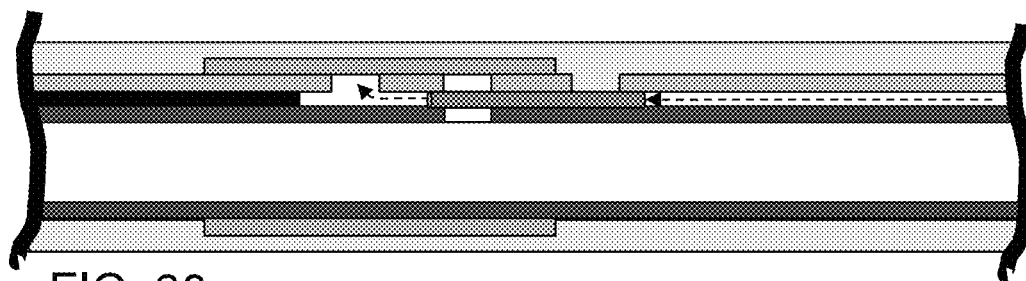


FIG. 30

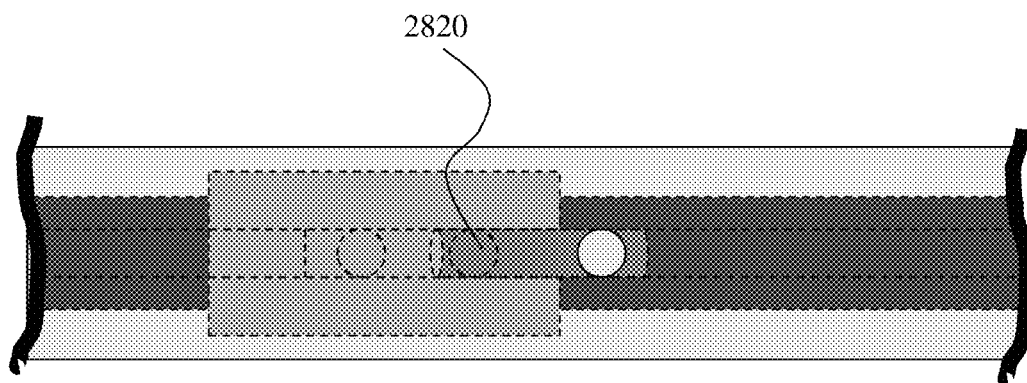


FIG. 31

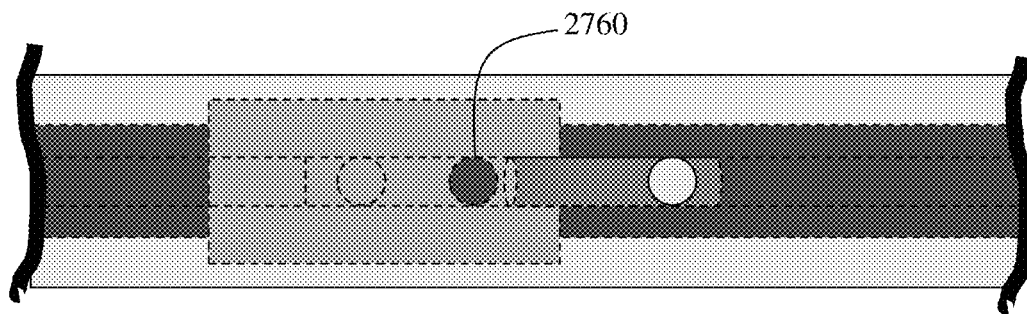
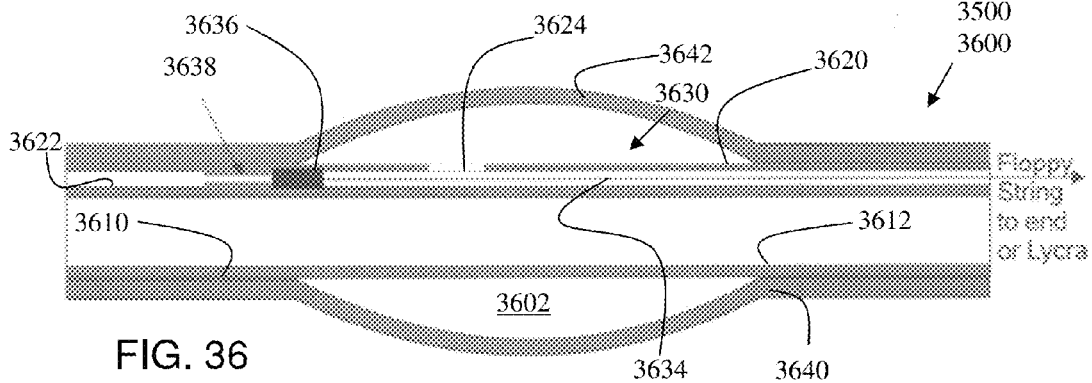
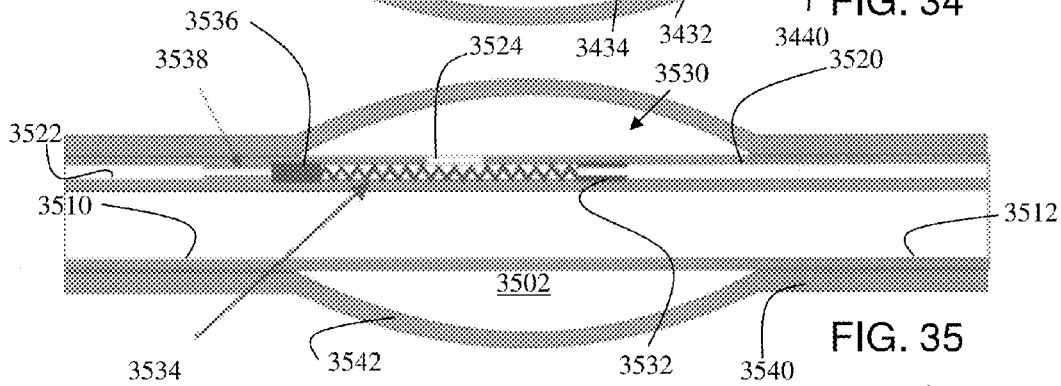
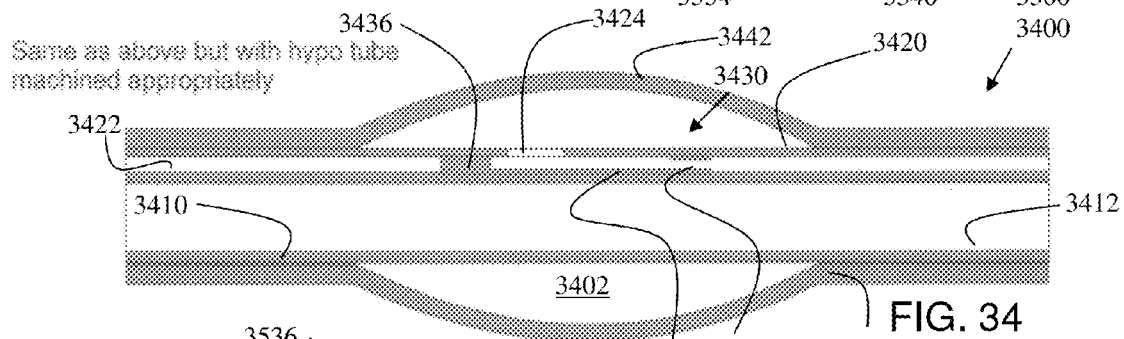
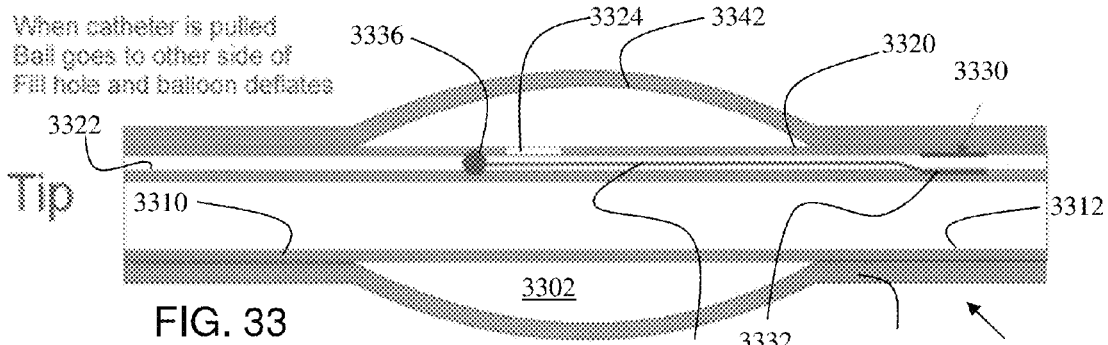
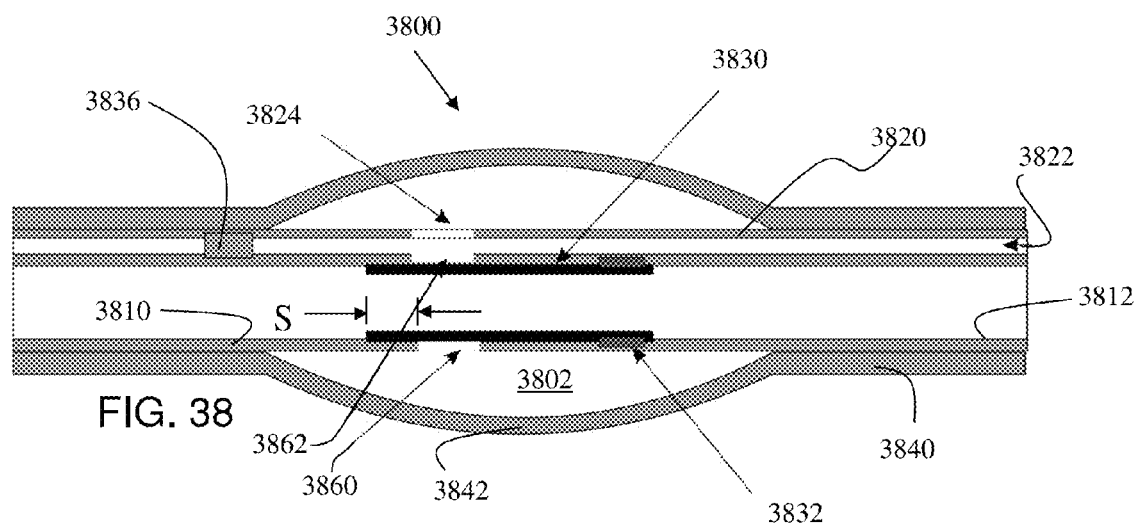
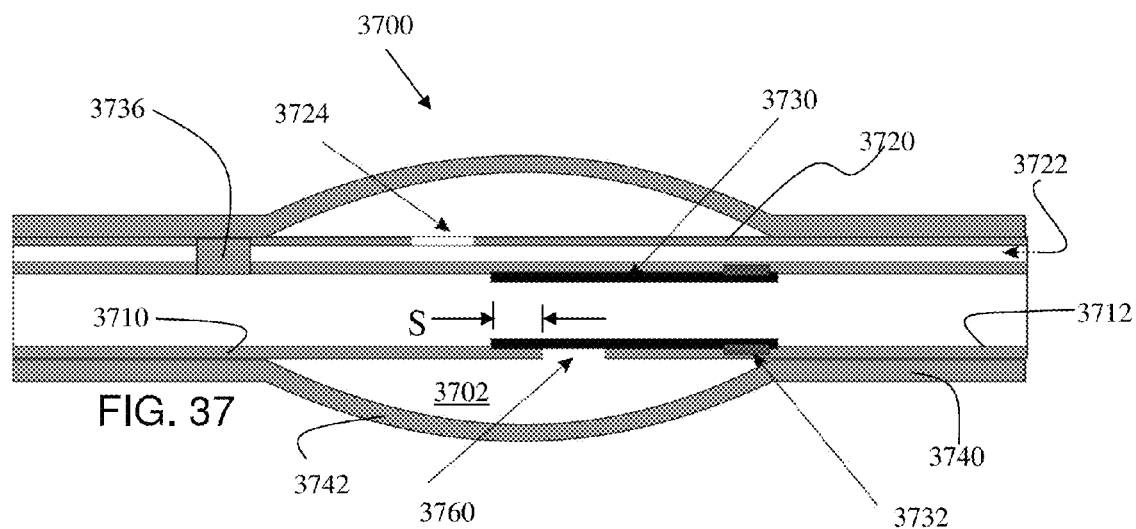


FIG. 32







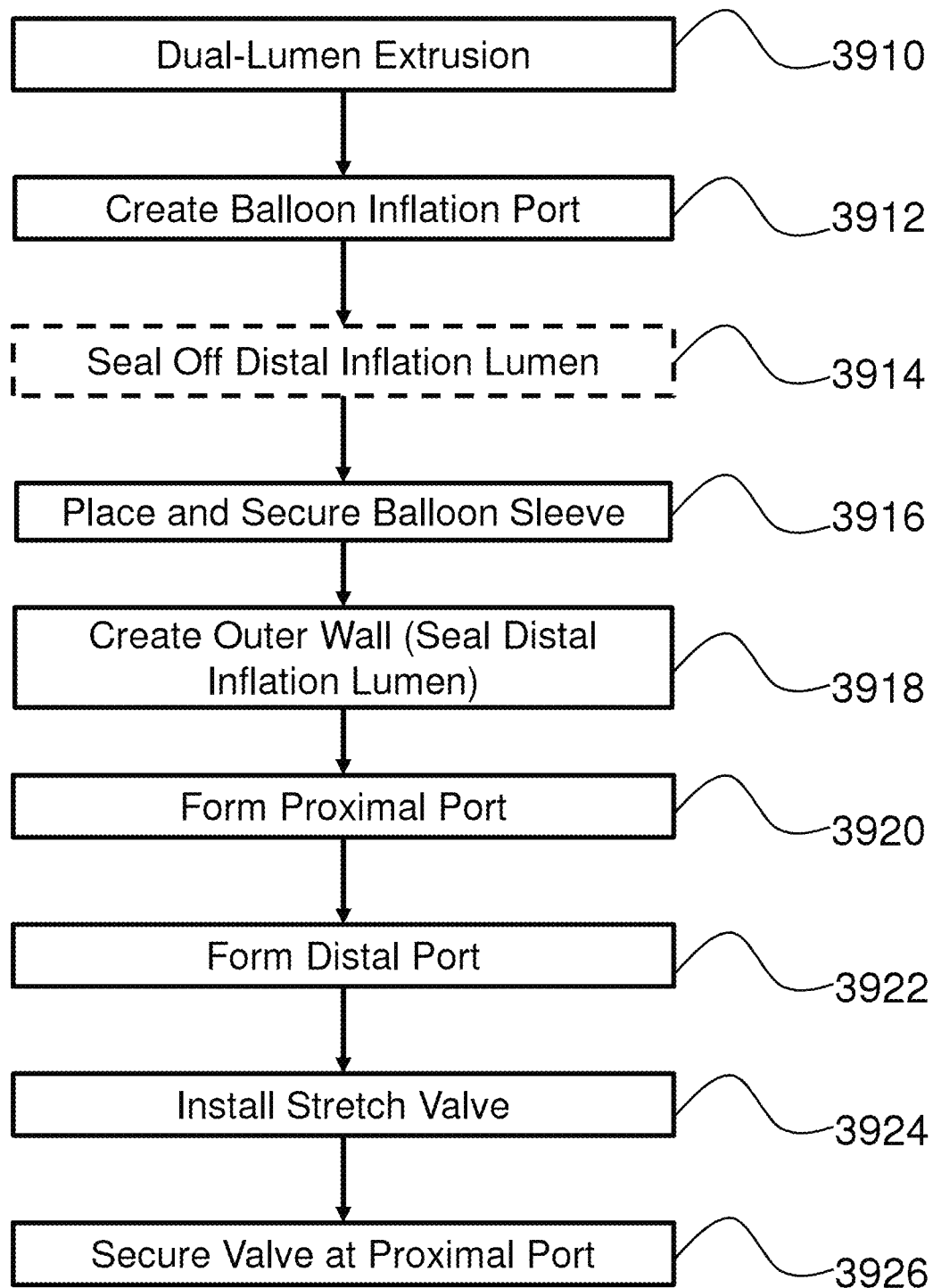


FIG. 39

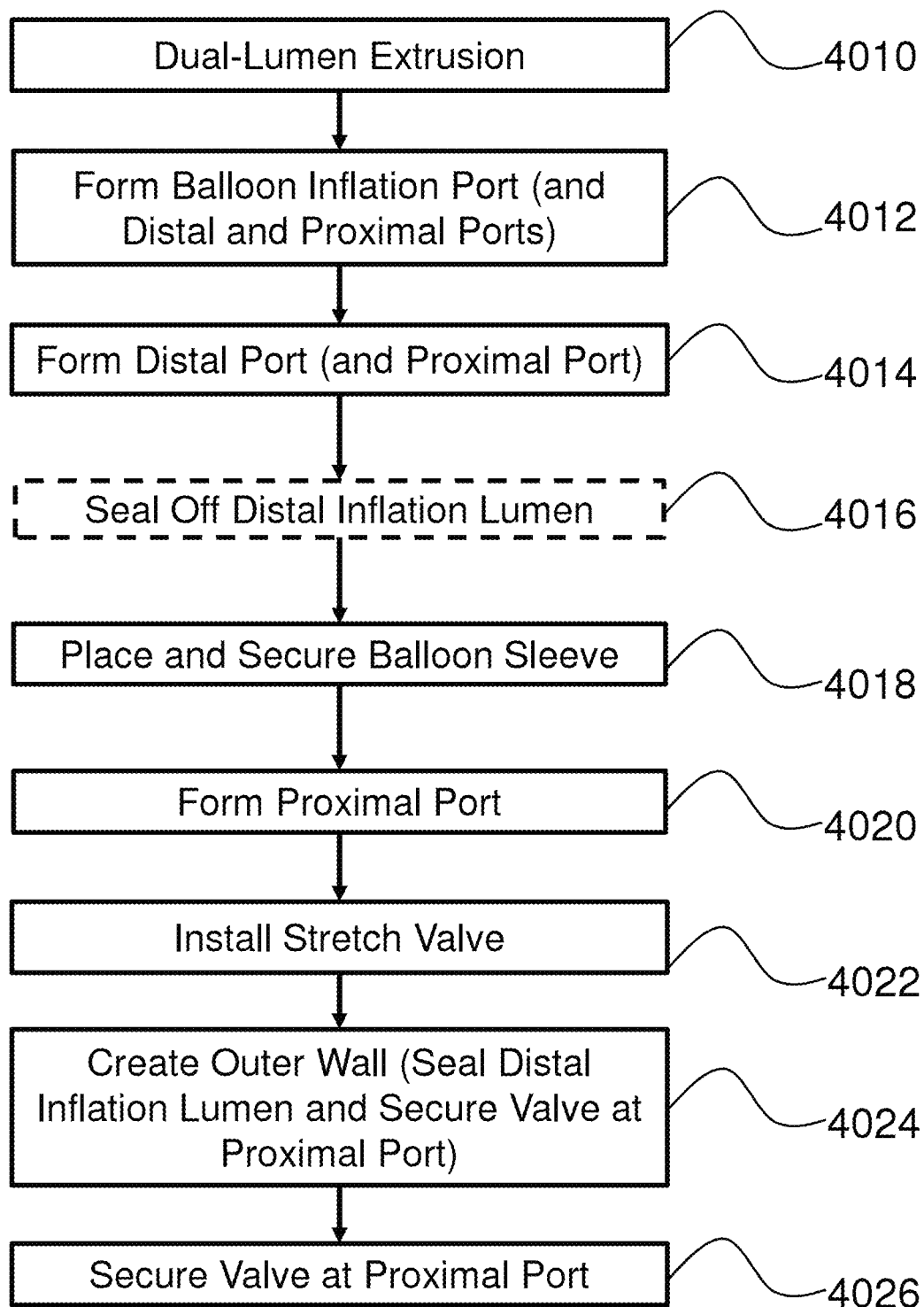


FIG. 40

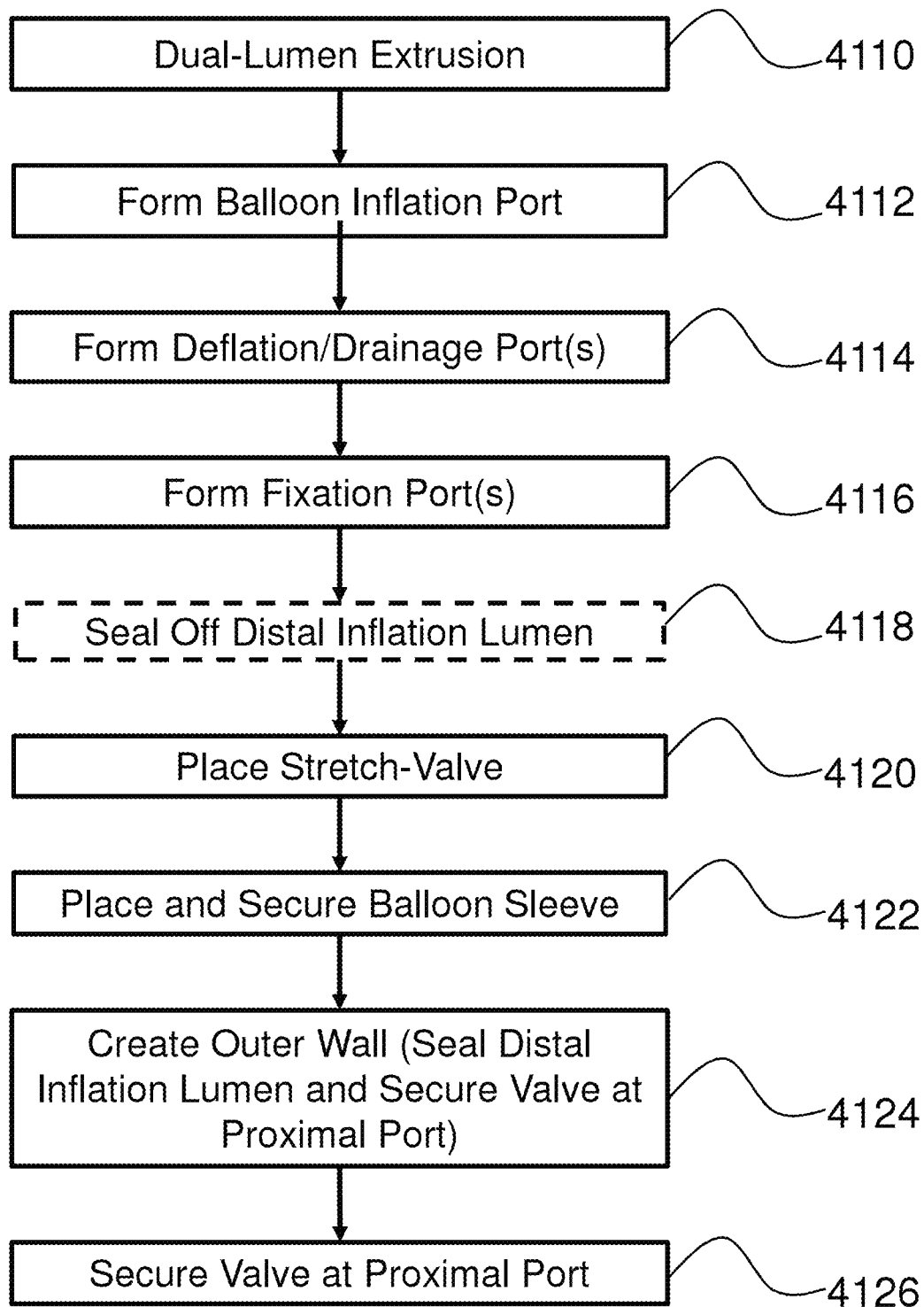
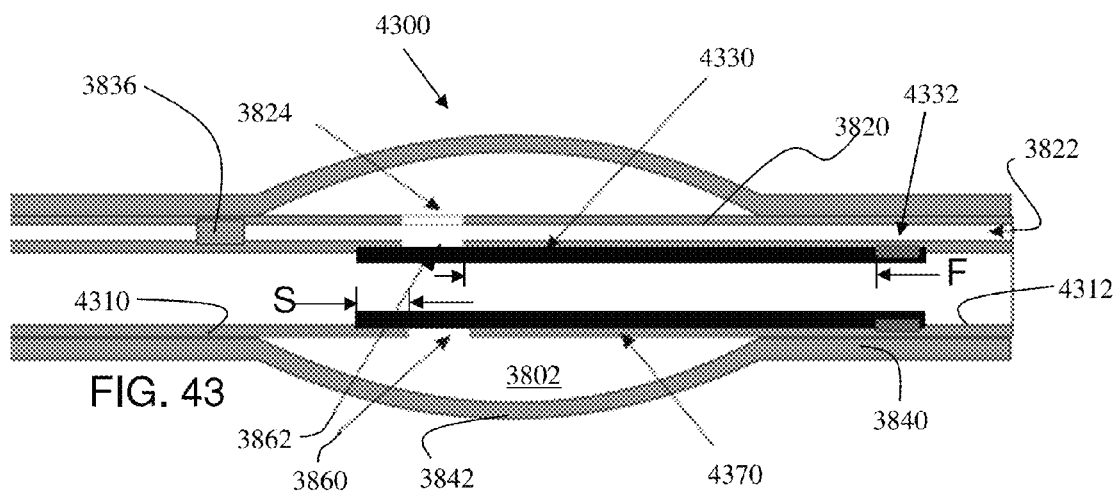
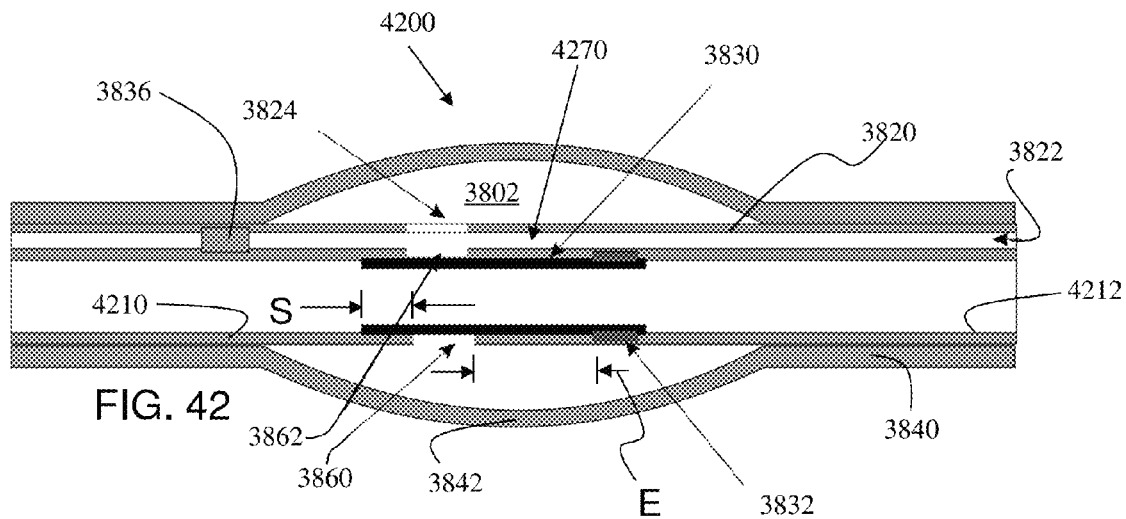


FIG. 41



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# STRETCH VALVE BALLOON CATHETER AND METHODS FOR PRODUCING AND USING SAME

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application:

claims the priority, under 35 U.S.C. §119, of U.S. Provisional Patent Application No. 61/637,690, filed Apr. 24, 2012;

is a continuation-in-part of U.S. patent application Ser. No. 11/339,258, filed Jan. 25, 2006, now U.S. Pat. No. 7,883,503 (which application claims the benefit under 35 U.S.C. §119(e) of U.S. Provisional Patent Application Nos. 60/647,204 and 60/647,205, both filed Jan. 26, 2005);

is a continuation-in-part of U.S. patent application Ser. No. 12/943,453, filed Nov. 10, 2010, now U.S. Pat. No. 8,382,708 (which application claims the benefit under 35 U.S.C. §119(e) of U.S. provisional application No. 61/260,271 filed Nov. 11, 2009), the prior applications are hereby incorporated herein by reference in their entirety; and

is a continuation-in-part of U.S. patent application Ser. No. 13/707,752, filed Dec. 7, 2012 (which application claims the benefit under 35 U.S.C. §119(e) of U.S. provisional application No. 61/637,690, filed Apr. 24, 2012).

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention relates to a catheter, especially an automatically deflating balloon catheter with a stretch valve and methods for using and manufacturing such a catheter.

### 2. Description of Related Prior Art

A number of conventional balloon catheters exist in the prior art. Some catheters are used to drain the bladder of a patient during surgical procedure or to treat bladder and/or urethra or prostate conditions, for example. For example, a common balloon catheter made by RUSCH® and referred to as a Foley catheter is widely used today for treating and draining a patient's bladder. The Foley catheter is shown in FIG. 1 and has a multi-lumen shaft 1 that is disposed in the urethra 10, a balloon portion 3 disposed at the distal end of the shaft 1, a fluid drain section 4 disposed at the distal end of the balloon 3, and a curved or straight, distal guiding tip 5 at the distal-most end of the entire catheter. When placed properly, the proximal-most side of the inflated balloon 3 rests on the interior wall 31 of the bladder 30, entirely blocking off the urethrovesical junction 11 connecting the bladder 30 and the urethra 10. In such a position, the fluid drain section 4 allows continuous drainage of the bladder 30 and the balloon 3 virtually entirely prevents the catheter from slipping out of the bladder. This ideally inserted position is shown in FIG. 1. As used herein, a fluid can be either a liquid or a gas. Exemplary fluids for inflating a balloon 3 are saline, sterile water, air, or carbon dioxide gas. Exemplary fluids drained by the catheters mentioned herein include urine and blood.

Basically, the catheter has a tube-like body with two lumens passing therethrough. The larger lumen is open to the bladder (distally) and empties into a non-illustrated ex-corporeal bag (proximally) for eventual disposal. A smaller lumen is used to inflate (and deflate) the balloon 3 with sterile water (typically) using a syringe attached to the inflation lumen fitting 260 (see, e.g., FIG. 3). When inflated in the

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bladder, for example, the catheter is substantially prevented from sliding out of the urethra in use.

In a conventional balloon 3, the balloon 3 has a substantially constant balloon wall thickness. The balloon 3 is fixed to the outer surface of a fluid drainage line (not illustrated in FIG. 1) and is not intended to be removed therefrom or to burst thereon unless an extraordinary amount of inflation occurs. If such an event happens, the material of the balloon will open at a random location based upon the microscopic fractures or weaknesses in the material itself. Such a tearing event is not supposed to occur under any circumstances during use with a patient.

Prior art catheters are not constructed to prevent tearing of the urethra during a catheter implanting procedure and are not constructed to break in any predefined way. Prior art catheters are designed to deflate only when actively deflated, either by a syringe similar to the one that inflated it or by surgery after the physician diagnoses the balloon as not being able to deflate, in which circumstance, a procedure to pop the balloon surgically is required.

Over 96 million indwelling catheters are sold worldwide on an annual basis. Twenty four million catheters are sold to hospitals in the U.S. There are numerous complications associated with those catheters that need to be prevented. These complications are responsible for increases in hospital stays, excessive bleeding, mortality, as well as morbidity. They also cause an increased expense and burden on the already-stressed health care system.

The complications result from several different mechanisms. First, and probably most common, is improper placement of the catheter. Because of the unique anatomy of the male urethra, placing a urethral catheter for urinary drainage can be difficult. A problem arises when the physician, technician, or nurse thinks that the catheter is actually in a proper position when it is not. The proper position for the catheter is with the balloon located in the cavity of the bladder. In this position, the tip distal to the balloon is located in the bladder and is used to drain the bladder cavity.

For placement of this catheter in the bladder 30 in the ideal position, however, the physician or technician has no visual aid. As shown in FIG. 1, the wall 40 defining the urethrovesical junction 11 is very short in the longitudinal direction of the urethra 10. If the physician inserts the catheter too far into the bladder 30, no damage occurs from balloon inflation; however, there is a possibility of leakage around the balloon 3, which, under normal conditions, actually helps to lubricate the urethra 10. In such a case, gentle proximal movement of the shaft 1 will place the proximal side of the balloon 3 against the urethrovesical junction 11. The bladder 30 can then easily expand and stretch to compensate for the balloon 3. A normal bladder capacity is 400 cc to 500 cc. A normal balloon capacity is approximately 10 cc to 12 cc although larger balloons are sometimes used. A typical balloon is 5 cc, however, most clinicians put 10 cc of water in the balloon for inflation. With 5 cc of water in the balloon, the diameter is approximately 2 cm and with 10 cc the diameter is approximately 2.5 cm.

Complications occur when the technician and/or nurse inflates the balloon when the balloon is not in the bladder. If the technician does not insert the catheter in far enough, then the balloon 3 will be inflated within the urethra 10—a condition that, while common, is to be avoided at all costs and is a frequent cause of bladder infections created during a hospital or clinic visit. Infections arise because inflation of the bladder 3 inside the urethra 10 causes the urethra 10 to stretch too far and tear. Even though the urethra 10 is a flexible tube, it has limits to which it can be safely stretched from within. Almost every balloon catheter has a balloon outer diameter/circum-

ference that well-exceeds the safe stretching limit of the urethra 10. Therefore, if the balloon catheter is not inserted far enough, inflation of the balloon 3 will cause serious injury to the urethra 10. This is especially true with elderly patients who have urethras that are not as elastic as younger patients. Also, just as important is the change in anatomy of older males, in particular, the prostatic portion of the urethra. With age, the prostate becomes larger and, sometimes, the catheter cannot be advanced through the prostatic portion of the urethra. When this occurs, the technician does not insert the catheter an the way into the bladder and inflates the balloon within the urethra. Alternatively, strictures, i.e., scar tissue, cause the catheter to halt and further pressure tears the urethral wall to create a new, unintended passage. Both of these improper insertions cause severe bleeding and damage.

The elastomeric balloon of present-day catheter products requires relatively high pressures to initiate inflation and expand to an expected full-diameter shape upon over-inflation. As such, when incorrectly placed in the urethra, the rapid inflation, combined with the high-pressure, causes the balloon to tear the surrounding membrane, referred to as the mucosa. Tearing of the urethra 10 in this way causes bleeding and allows bacteria to enter into the bloodstream at the tear site, thus causing the subsequent bladder infection. Significant bleeding can become life threatening. The urethra can normally dilate several millimeters; however, when the balloon is inflated, this dilation is usually several centimeters. Also, without sufficient and immediate venting of the balloon inflation fluid after improper placement, an accidental or intentional pull on the catheter externally can and does cause extensive bodily harm to the patient.

Life threatening bleeds, especially in patients who are anticoagulated, can and do occur. Also when the urine is infected, as in immunocompromised patients and the elderly, the bacteria enter the blood stream and can cause serious infections (e.g., sepsis), which frequently can lead to death. If the patient survives the initial trauma, then long-term complications, such as strictures, can and usually do occur. Strictures cause narrowings within the urine channel and usually require additional procedures and surgeries to correct.

Other mechanisms of catheter-induced injuries are inadvertent manipulation of the tubing or dislodging of the balloon—caused when the catheter is pulled from outside the patient due to a sudden jerk or tension. This commonly happens when the patient is ambulating or traveling from the bed to the commode or bathroom. The tubing may inadvertently become fixed while the patient is still moving, at which time a sudden jerk is imparted upon the balloon and pulls the balloon into the urethra, which tears the urethra, causing severe pain and bleeding. Injury caused by the improper, inadvertent, and/or early removal of an inflated balloon catheter is referred to as iatrogenic injury (also referred to as an in-hospital injury). Hundreds of thousands of such iatrogenic injuries occur each year—all of which need to be prevented, not only for patient safety, but also because the cost imposed on the medical health industry for each injury is enormous.

Yet another scenario occurs when the patient deliberately pulls on the catheter, thereby causing self-induced pain and injury to the urethra. This commonly happens in confused patients, for example, patients in nursing homes who have a disease or cognitive dysfunction problem, such as Alzheimer's disease, or other diseases that make the patient unable to understand the necessity of having a catheter. Confusion occurs when the patient has a spasm causing pain and a strong urge to urinate. During the spasm, the confused patient often tugs and pulls on a catheter, which results in injury. Like iatrogenic injuries, these self-induced injuries must be pre-

vented. In the particular case of injury caused by catheter withdrawal when the balloon is inflated (either iatrogenic or self-induced), hospitals have categorized such injuries as "never events"—occurrences that should never happen. Under such circumstances, insurance typically does not cover the resulting extensive medical expenses.

The injuries mentioned herein are not limited to males and also cause severe damage to the female bladder and urethra. The injuries can also occur post-surgically, which makes the damage even more severe. One common situation where injury is caused is when the patient is medicated with morphine or other analgesics that render the patient confused and unable to make rational decisions. Feeling the foreign body inside the urethra, the confused patient does not know to leave it alone and, instead, gives it the injury-causing tug. These injuries have been well-documented and are not limited to adults. Numerous injuries are documented in pediatric patients.

Usually, it takes time to make a diagnosis of patient-caused catheter injury. Immediately after diagnosing the injury, a technician needs to deflate the catheter. However, once the urethra is torn, replacing the damaged catheter with another catheter is quite difficult and, in fact, exacerbates the injury. Sometimes, the patient has to be taken to the operating room to replace a urinary drainage tube once the injury occurs. Because catheters and leg bags are now used routinely in certain situations during home health care, this scenario is not limited to hospitals and occurs at nursing homes and patients' homes as well.

Most of the recent catheter technology has been focused on reducing urinary tract infections that are caused by catheters, injuries that are usually the most common catheter-related complications. One example of such technology is impregnation of the catheter with antimicrobials or antibiotics. But, these advances do nothing to prevent the injuries explained herein.

Accordingly, it would be beneficial to provide a balloon catheter that does not inflate past the tearing limit of a urethra and deflates in a desired, predefined way under certain conditions.

## SUMMARY OF THE INVENTION

It is accordingly a desire to provide an automatically deflating pressure balloon catheter with a stretch valve and methods for manufacturing and using the catheter that overcome the hereinafore-mentioned disadvantages of the heretofore-known devices and methods of this general type and quickly and rapidly deflates if pulled out prior to physician-scheduled deflation of the balloon.

With the foregoing and other objects in view, there is provided, in accordance with the invention, a flexible, multi-lumen shaft having an outer diameter, a distal tip, a proximal catheter end with a drain end, a proximal inflation end, and a hollow stretch valve. The multi-lumen shaft defines a drain lumen extending through the shaft and operable to drain fluid adjacent the distal tip therethrough and out the proximal drain end, a distal hollow balloon portion defining a balloon interior and having at least one inflation port fluidically connected to the balloon interior, the balloon portion operable to be inflated outwardly through the at least one inflation port to a diameter greater than the outer diameter of the shaft, at least one inflation lumen parallel to the drain lumen and fluidically connected to the at least one inflation port, the at least one inflation lumen operable to inflate the balloon interior with an inflation fluid, and a drainage port. The drainage port fluidically connects at least one of the balloon interior and the at

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least one inflation lumen to at least one of the drain lumen and the environment of the balloon portion. The hollow stretch valve is coaxially disposed in the at least one inflation lumen and operable to permit the inflation fluid to pass therethrough, is positioned in the at least one inflation lumen to prevent fluid from passing through the drainage port in a steady state, has a distal valve end and a proximal valve end, has a fixed portion fixedly connected within the at least one inflation lumen at one of the distal valve end and the proximal valve end, and has a sliding portion slidably disposed within the at least one inflation lumen at the other one of the distal valve end and the proximal valve end such that, in a stretched state when the proximal catheter end is stretched, the sliding portion slides within the at least one inflation lumen to permit the inflation fluid to pass through the drainage port. The multi-lumen shaft has an extent distal of the connection of the fixed portion that is relatively more stretchable than at least a portion of the multi-lumen shaft proximal of the extent.

With the objects of the invention in view, there is also provided a safety catheter, comprising a flexible, multi-lumen shaft having an outer diameter, a distal tip, a proximal catheter end with a drain end, a proximal inflation end, and a hollow stretch valve. The multi-lumen shaft defines a drain lumen extending through the shaft and operable to drain fluid adjacent the distal tip therethrough and out the proximal drain end, a distal hollow balloon portion defining a balloon interior and having at least one inflation port fluidically connected to the balloon interior, the balloon portion operable to be inflated outwardly through the at least one inflation port to a diameter greater than the outer diameter of the shaft, at least one inflation lumen parallel to the drain lumen and fluidically connected to the at least one inflation port, the at least one inflation lumen operable to inflate the balloon interior with an inflation fluid, and a drainage port fluidically connecting the balloon interior to the drain lumen. The hollow stretch valve is coaxially disposed in the drain lumen and operable to permit fluid to pass therethrough, is positioned in the drain lumen to prevent fluid from passing through the drainage port in a steady state, has a distal valve end and a proximal valve end, has a fixed portion fixedly connected within the drain lumen at one of the distal valve end and the proximal valve end, and has a sliding portion slidably disposed within the drain lumen at the other one of the distal valve end and the proximal valve end such that, in a stretched state when the proximal catheter end is stretched, the sliding portion slides within the drain lumen to permit the inflation fluid to pass through the drainage port. The multi-lumen shaft having an extent distal of the connection of the fixed portion that is relatively more stretchable than at least a portion of the multi-lumen shaft proximal of the extent.

In accordance with another feature of the invention, the stretch valve has the stretched state at a pull force of between approximately 1 pound and approximately 15 pounds applied to the proximal shaft portion.

In accordance with a further feature of the invention, the stretch valve has the stretched state at a pull force of between approximately 1 pound and approximately 5 pounds applied to the proximal shaft portion.

In accordance with an added feature of the invention, the stretch valve has the stretched state at a pull force of between approximately 1.5 pounds and approximately 2 pounds applied to the proximal shaft portion.

In accordance with an additional feature of the invention, when the balloon portion is inflated with a fluid and a pull force of greater than approximately 15 pounds is applied to

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the proximal shaft portion, the stretch valve meets the stretched state and thereby deflates the inflated hollow balloon.

In accordance with yet another feature of the invention, when the balloon portion is inflated with a fluid and a pull force of greater than approximately 5 pounds is applied to the proximal shaft portion, the stretch valve meets the stretched state and thereby deflates the inflated hollow balloon.

In accordance with yet a further feature of the invention, when the balloon portion is inflated with a fluid and a pull force of greater than approximately 2 pounds is applied to the proximal shaft portion, the stretch valve meets the stretched state and thereby deflates the inflated hollow balloon.

In accordance with yet an added feature of the invention, the drainage port fluidically connects at least one of the balloon interior and the at least one inflation lumen to at least one of the drain lumen, the environment proximal of the balloon portion, and the environment distal of the balloon portion.

In accordance with yet an additional feature of the invention, the drainage port is a plurality of drainage ports fluidically connecting at least one of the balloon interior and the at least one inflation lumen to at least one of the drain lumen and the environment of the balloon portion.

In accordance with again another feature of the invention, the drainage port fluidically connects the balloon interior and the inflation lumen to the drain lumen.

In accordance with another feature of the invention, the fixed portion of the hollow stretch valve is proximal of the proximal end of the balloon.

In accordance with a concomitant feature of the invention, the drainage port is a plurality of drainage ports each fluidically connecting the balloon interior to the drain lumen and the hollow stretch valve is positioned in the drain lumen to prevent fluid from passing through the plurality of drainage ports in a steady state and has the sliding portion slidably disposed within the drain lumen such that, in a stretched state when the proximal catheter end is stretched, the sliding portion slides within the drain lumen to permit the inflation fluid to pass through the plurality of drainage ports.

The low-pressure balloon catheter of the present invention prevents injury by having the balloon automatically deflate before an injury can occur, for example, when being forced to withdraw from the bladder or being forced to inflate within a urethra. The stretch valve balloon catheter of the present invention prevents injury by having the balloon automatically deflate before an injury can occur, for example, when being forced to withdraw from the bladder prior to physician-scheduled manual deflation. While the catheters of the present invention makes it a safer device for urinary drainage, the present invention can also be used for any procedures in which balloons are used to occlude cavities. Examples of these procedures include coronary artery vessels and peripheral vascular vessels, such as the aorta and extremity vessels. Balloon dilations of other lumens, such as ureters and the esophagus, are also candidates for use of the catheter of the present invention. Further, the mechanism of pressure release can be used for any fluid or air-filled device such as tissue expanders, percutaneous devices, and the like.

Some of the embodiments of the present invention utilize a valve (e.g., a slit valve or a stretch valve) that permits reuse when utilized. With embodiments having no such valves, the invention is a single use catheter after deflation occurs. Although deflation of such a single-use catheter renders it useless, the act of immediate deflation protects the patient from serious harm and the cost of replacing a catheter is minimal as compared to the significant cost of treating catheter-induced injury. Prevention of such injuries is becoming



more and more important because the injuries are commonplace. The increase occurs for a number of reasons. First, a greater percentage of the population is aging. Second, there is a current trend to use less-skilled health care personnel to perform more procedures and to be responsible for treatment, both of which save the hospitals and doctors money. The shortage of nursing professionals (e.g., R.N.s) exacerbates this trend. The present tendency is to use nursing professionals for more functions, such as administration and delivery of medications. This leaves only the least-skilled technicians with the task of taking vital signs and inserting catheters. Under such circumstances, more injuries are likely and do, in fact, occur. Lastly, catheter-related complications are becoming more severe due to the increased use of anticoagulation medication, such as PLAVIX®, that is frequently prescribed in treating cardiovascular disease.

Yet another possible complication arising from the standard Foley catheter is that the balloon will not deflate even when the deflation mechanism is activated. This situation can occur, for example, because the wrong fluid is used to inflate the balloon or when a fluid, such as saline, crystallizes, which happens occasionally. Sometimes, the ability to deflate the catheter is interrupted because the drainage channel that is used to deflate the balloon becomes obstructed, which is common if the catheter is left in place too long. Remedy of such a scenario involves an invasive procedure, which includes threading a needle or other sharp object somewhere through the body cavity to puncture the balloon and, thus, dislodge the catheter. This procedure is not desirable and is to be avoided if possible. Yet another possible complication can occur when the patient has a stricture, i.e., scar tissue in the urethra that impedes the passage of the catheter. When a technician is faced with a stricture, it seems to the technician that the catheter is no longer moving towards the bladder. Consequently, the technician uses excessive force to push the catheter into the bladder, thereby causing a tear that creates its own lumen into the penile and prostatic tissue. As is self-evident, this situation is accompanied by significant bleeding and the need for additional corrective procedures and surgery.

With the low-pressure or valved, auto-deflating balloons of the present invention, the technician, nurse, or doctor merely needs to pull on the catheter to cause the catheter to automatically deflate, thus sparing the patient from any additional surgical procedures.

The added benefit of the present invention is not just for safety, significant financial benefits arise as well. It is believed that catheter-induced injuries are much more common than public documentation suggests. Catheter-related trauma occurs no less than once a week in a large metropolitan hospital. Usually, each incident not only increases the patient's hospital stay substantially, but also the expense of the stay. Each incident (which is usually not reimbursed by insurance) can increase the cost to the hospital by thousands of dollars, even tens or hundreds of thousands of dollars. This is especially true when the patient brings a personal injury action against the hospital, physician(s), and/or staff. And, when additional surgery is required to repair the catheter-induced injury, increased expense to the hospital is not only substantial, if litigation occurs as a result of the injury, damages awarded to the patient can run into the millions of dollars. The catheters and methods of the present invention, therefore, provide a safer catheter that has the possibility of saving the medical industry billions of dollars.

To prevent urethra tearing occurrences due to premature-improper inflation of the balloon and/or due to premature removal of an inflated balloon, an exemplary embodiment of the invention of the instant application provides various bal-

loon safety valves. Such valves are configured to release the inflation liquid from the balloon before injury occurs.

The maximum stress that a typical urethra can take without tearing and/or breaking is known and is referred to as a maximum urethra pressure. It is also possible to calculate how much pressure is exerted upon the exterior of a balloon of a balloon catheter by measuring the pressure required to inflate the balloon. Knowing these two values, it is possible to construct a balloon that breaks rapidly and/or ceases inflation if the maximum urethra pressure is exceeded.

For example, in a first exemplary embodiment, the balloon, which is typically some kind of rubber, silicone, elastomer, or plastic, can be made with a breaking point that instantly deflates the balloon if the pressure in the balloon exceeds the maximum urethra pressure. It is acknowledged and accepted that, once the balloon breaks, this catheter is useless and must be discarded because the cost of patient injury far outweighs the cost of the disposable catheter. Also, such a balloon is limited to inflation with a bio-safe fluid to prevent unwanted air/gas from entering the patient. If, however, air or other gas will not injure the patient, the fluid can be air or another gas.

As an alternative to a one-use breaking safety valve, a multi-use pressure valve can be added to the balloon inflation lumen and can be set to open into the drainage lumen if the maximum urethra pressure is exceeded in the balloon or the balloon inflation lumen. Such a valve can be located near or at the balloon inflation port, for example. Any combination of the above embodiments is envisioned as well.

Another exemplary embodiment of the present invention provides the catheter with a balloon that inflates with virtually no pressure. As used herein, "virtually no pressure," "zero-pressure" and "low-pressure" are used interchangeably and are defined as a range of pressure between approximately standard atmospheric pressure and 0.3 atmospheres (5 psig). This is in contrast to "high-pressure," which is greater than approximately 1.5 atmospheres (22 psig). With such a configuration, the zero-pressure balloon can be deflated with virtually no force. As such, when the clinician attempts to inflate the zero-pressure balloon of the present invention within a urethra, the balloon simply does not inflate. Likewise, when the already inflated balloon within the bladder is forced into the urethra, such deflation needs virtually no pressure to collapse the balloon to fit into the urethra. In both circumstances, injury to the urethra is entirely prevented.

Further exemplary embodiments of the present invention that prevents urethra tearing occurrences due to premature removal of an inflated balloon provides a balloon catheter with a stretch valve and methods for manufacturing and using such a valved catheter. In these variations, the invention takes advantage of the fact that premature removal of the inflated balloon catheter requires stretching of the catheter at the proximal side of the balloon. The valved catheter can be configured with a release mechanism that is a function of elongation. With short elongations, the balloon remains inflated however, when pulled beyond a preset limit, the valve automatically opens and drains the fluid filling the balloon. Some variations allow the balloon to even be refilled if deflation occurs without any injury. In either case, injury is prevented. Description of one exemplary embodiment herein in a way that separate from other exemplary embodiments is not to be construed mean that the one embodiment mutually exclusive of the other exemplary embodiments. The various exemplary embodiments of the safety catheter mentioned herein can be used separately and individually or they can be used together in any combination.

Although some variations are illustrated and described herein as embodied in a stretch valve balloon catheter and

methods for producing and using such a catheter, they are, nevertheless, not intended to be limited to the details shown because various modifications and structural changes may be made therein without departing from the spirit of the invention and within the scope and range of equivalents of the claims. Additionally, well-known elements of exemplary embodiments of the invention will not be described in detail or will be omitted so as not to obscure the relevant details of the invention.

Other features that are considered as characteristic for the invention are set forth in the appended claims. As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one of ordinary skill in the art to variously employ the present invention in virtually any appropriately detailed structure. Further, the terms and phrases used herein are not intended to be limiting; but rather, to provide an understandable description of the invention. While the specification concludes with claims defining the features of the invention that are regarded as novel, it is believed that the invention will be better understood from a consideration of the following description in conjunction with the drawing figures, in which like reference numerals are carried forward. The figures of the drawings are not drawn to scale.

Before further disclosure and description, it is to be understood that the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. The terms “a” or “an”, as used herein, are defined as one or more than one. The term “plurality,” as used herein, is defined as two or more than two. The term “another,” as used herein, is defined as at least a second or more. The terms “including” and/or “having,” as used herein, are defined as comprising (i.e., open language). The term “coupled,” as used herein, is defined as connected, although not necessarily directly, and not necessarily mechanically.

As used herein, the term “about” or “approximately” applies to all numeric values, whether or not explicitly indicated. These terms generally refer to a range of numbers that one of skill in the art would consider equivalent to the recited values (i.e., having the same function or result). In many instances these terms may include numbers that are rounded to the nearest significant figure. In this document, the term “longitudinal” should be understood to mean in a direction corresponding to an elongated direction of the catheter. Lastly, the term “proximal” refers to the end of the catheter closest to the person inserting the catheter and is usually that end of the catheter with a hub. The distal end of the catheter is the end furthest away from the person inserting the catheter.

#### BRIEF DESCRIPTION OF THE DRAWINGS

In the following, the invention will be described in more detail by exemplary embodiments and the corresponding figures. By schematic illustrations that are not true to scale, the figures show different exemplary embodiments of the invention.

FIG. 1 is a diagrammatic, fragmentary, longitudinal cross-sectional view of a prior art catheter ideally placed in a urethra and a bladder of a male patient;

FIG. 2 is a fragmentary, enlarged, longitudinal cross-sectional view of a distal portion of a first embodiment of a pressure-limiting balloon catheter according to the invention;

FIG. 3 is a fragmentary, enlarged longitudinal cross-sectional view of a proximal portion of a second embodiment of a pressure-limiting balloon catheter according to the invention;

FIG. 4 is a fragmentary, enlarged, cross-sectional view of a first alternative configuration of the safety valve of FIG. 3;

FIG. 5 is a fragmentary, enlarged, cross-sectional view of a second alternative configuration of the safety valve of FIG. 3;

FIG. 6 is a fragmentary, enlarged, cross-sectional view of a third alternative configuration of the safety valve of FIG. 3;

FIG. 7 is a fragmentary, further enlarged, cross-sectional view of the safety valve of FIG. 6;

FIG. 8 is a fragmentary, further enlarged, cross-sectional view of a fourth alternative configuration of the safety valve of FIG. 3;

FIG. 9 is a fragmentary, partially hidden, perspective view of an exemplary embodiment of a zero-pressure safety catheter according to the invention;

FIG. 10 is a radial cross-sectional view of a portion of the catheter of FIG. 9 at section line 10-10;

FIG. 11 is a process flow diagram of an exemplary method of forming a zero-pressure balloon according to the invention;

FIG. 12 is a process flow diagram of an exemplary method of attaching a zero-pressure balloon according to the invention;

FIG. 13 is a fragmentary, enlarged, perspective view of a distal portion of an exemplary embodiment of a zero-pressure catheter according to the invention;

FIG. 14 is a radial cross-sectional view of a slit-valve portion of the catheter of FIG. 13 at section line 14-14;

FIG. 15 is a radial cross-sectional view of an alternative embodiment of a slit-valve portion of the catheter of FIG. 13 at section line 15-15;

FIG. 16 is a fragmentary, enlarged, partially cross-sectional and partially perspective view of an everting balloon catheter according to the invention in a correctly inserted position in the bladder;

FIG. 17 is a fragmentary, enlarged, partially cross-sectional and partially perspective view of the catheter of FIG. 16 being pulled distally out of the bladder and beginning its everting deflation;

FIG. 18 is a fragmentary, enlarged, partially cross-sectional view of the catheter of FIG. 16 with the everting deflation complete;

FIG. 19 is a fragmentary, enlarged, longitudinal cross-sectional view of a balloon portion of a prior art urinary catheter in an uninflated state;

FIG. 20 is a fragmentary, enlarged, longitudinal cross-sectional view of the prior art urinary catheter of FIG. 19 in an inflated state within a bladder;

FIG. 21 is a fragmentary, enlarged, longitudinal cross-sectional view of a balloon portion of an exemplary embodiment of an automatically deflating, stretch valve urinary balloon catheter according to the invention with the balloon in an uninflated state;

FIG. 22 is a fragmentary, enlarged, longitudinal cross-sectional view of the automatically deflating, stretch valve urinary balloon catheter of FIG. 21 with the balloon in an inflated state and with the stretch valve in an unactuated state;

FIG. 23 is a fragmentary, enlarged, longitudinal cross-sectional view of the automatically deflating, stretch valve urinary balloon catheter of FIG. 21 with the balloon in an inflated state and with the stretch valve in an actuated state;

FIG. 24 is a fragmentary, enlarged, longitudinal cross-sectional view of a balloon portion of another exemplary

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embodiment of an automatically deflating, stretch valve urinary balloon catheter according to the invention with the balloon in an uninflated state;

FIG. 25 is a fragmentary, enlarged, longitudinal cross-sectional view of the automatically deflating, stretch valve urinary balloon catheter of FIG. 24 with the balloon in an inflated state and with the stretch valve in an unactuated state;

FIG. 26 is a fragmentary, enlarged, longitudinal cross-sectional view of the automatically deflating, stretch valve urinary balloon catheter of FIG. 24 with the balloon in an inflated state and with the stretch valve in an actuated state;

FIG. 27 is a fragmentary, enlarged, longitudinal cross-sectional view of a balloon portion of still another exemplary embodiment of an automatically deflating, stretch valve urinary balloon catheter according to the invention with the balloon in an uninflated state;

FIG. 28 is a fragmentary, enlarged, longitudinal cross-sectional view of the automatically deflating, stretch valve urinary balloon catheter of FIG. 27 with the balloon in an inflated state and with the stretch valve in an unactuated state;

FIG. 29 is a fragmentary, enlarged, longitudinal cross-sectional view of the automatically deflating, stretch valve urinary balloon catheter of FIG. 27 with the balloon in an inflated state and with the stretch valve in an actuated state;

FIG. 30 is a fragmentary, enlarged, longitudinal cross-sectional view of the automatically deflating, stretch valve urinary balloon catheter of FIG. 27;

FIG. 31 is a fragmentary, enlarged, longitudinal cross-sectional view of the automatically deflating, stretch valve urinary balloon catheter of FIG. 27 turned ninety degrees counterclockwise when viewed from a proximal end thereof and with the stretch valve in an unactuated state;

FIG. 32 is a fragmentary, enlarged, longitudinal cross-sectional view of the automatically deflating, stretch valve urinary balloon catheter of FIG. 27 turned ninety degrees counterclockwise when viewed from a proximal end thereof and with the stretch valve in an actuated state;

FIG. 33 is a fragmentary, enlarged, longitudinal cross-sectional view of a balloon portion of yet another exemplary embodiment of an automatically deflating, stretch valve urinary balloon catheter according to the invention with the balloon in a partially inflated state and the stretch valve in an unactuated state;

FIG. 34 is a fragmentary, enlarged, longitudinal cross-sectional view of a balloon portion of yet a further exemplary embodiment of an automatically deflating, stretch valve urinary balloon catheter according to the invention with the balloon in a partially inflated state and the stretch valve in an unactuated state

FIG. 35 is a fragmentary, enlarged, longitudinal cross-sectional view of a balloon portion of still a further exemplary embodiment of an automatically deflating, stretch valve urinary balloon catheter according to the invention with the balloon in a partially inflated state and the stretch valve in an unactuated state;

FIG. 36 is a fragmentary, enlarged, longitudinal cross-sectional view of a balloon portion of an additional exemplary embodiment of an automatically deflating, stretch valve urinary balloon catheter according to the invention with the balloon in a partially inflated state and the stretch valve in an unactuated state;

FIG. 37 is a fragmentary, enlarged, longitudinal cross-sectional view of a balloon portion of another exemplary embodiment of an automatically deflating, stretch valve urinary balloon catheter according to the invention with the balloon in a partially inflated state and the stretch valve in an unactuated state;

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FIG. 38 is a fragmentary, enlarged, longitudinal cross-sectional view of a balloon portion of still another exemplary embodiment of an automatically deflating, stretch valve urinary balloon catheter according to the invention with the balloon in a partially inflated state and the stretch valve in an unactuated state;

FIG. 39 is a flow chart of exemplary embodiments of processes for making a catheter according to the invention;

FIG. 40 is a flow chart of exemplary embodiments of other processes for making a catheter according to the invention;

FIG. 41 is a flow chart of exemplary embodiments of further processes for making a catheter according to the invention;

FIG. 42 is a fragmentary, enlarged, longitudinal cross-sectional view of a balloon portion of another exemplary embodiment of an automatically deflating, stretch valve urinary balloon catheter according to the invention with the balloon in a partially inflated state and the stretch valve in an unactuated state; and

FIG. 43 is a fragmentary, enlarged, longitudinal cross-sectional view of a balloon portion of still another exemplary embodiment of an automatically deflating, stretch valve urinary balloon catheter according to the invention with the balloon in a partially inflated state and a longer stretch valve in an unactuated state.

#### DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

While the specification concludes with claims defining the features of the invention that are regarded as novel, it is believed that the invention will be better understood from a consideration of the following description in conjunction with the drawing figures, in which like reference numerals are carried forward.

Herein various embodiment of the present invention are described. In many of the different embodiments, features are similar. Therefore, to avoid redundancy, repetitive description of these similar features may not be made in some circumstances. It shall be understood, however, that description of a first-appearing feature applies to the later described similar feature and each respective description, therefore, is to be incorporated therein without such repetition.

Referring now to the figures of the drawings in detail and first, particularly to FIG. 2 thereof, there is shown a first embodiment of a pressure-limiting balloon catheter 100 that does not inflate past the tearing limit of a lumen in which the catheter 100 is placed, for example, in the urethra.

To prevent occurrences of urethra tearing due to premature-improper inflation of the balloon and/or due to premature removal of an inflated balloon, the invention of the instant application provides the balloon 110 with a balloon safety valve 112. As set forth above, in a balloon 3 of a conventional catheter (see reference numerals 1 to 5 in FIG. 1), the high-pressure balloon 3 is fixed to the outer surface of the fluid drainage lumen 120 (not shown in FIG. 1) and is not intended to be removed therefrom or to burst thereon unless an extraordinary amount of inflation occurs. Such a tearing event is not supposed to occur under any circumstances during use with a patient. If such an event happens, the material of the balloon 3 will open at a random location, based upon the microscopic fractures or weaknesses in the material itself, and risk serious damage to the patient associated with the bursting, as well as a risk of balloon fragmentation, which could leave one or more pieces of the balloon 3 inside the patient after removal of the catheter 1.

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In contrast to such conventional devices, the balloon **110** of the present invention is created specifically to tear when a predefined pressure exists in or is exerted on the balloon **110**. The controlled tear will occur because the balloon safety valve **112** is present. Conventional balloons have constant balloon wall thicknesses (before inflation). In contrast thereto, the balloon safety valve **112** in the first embodiment is a defined reduction in balloon wall thickness. This reduction creates a breaking point or selected breaking points at which the balloon **110** is intended specifically to break when a predefined force exists in or is imparted on the balloon **110**. Because the balloon **110** is made of a material having a known tearing constant—dependent upon the thickness thereof. (which is determined experimentally for different thicknesses of a given material prior to use in a patient), the balloon safety valve **112** of the present invention for urethra applications is matched to break when the pressure inside or exerted on the balloon **110** approaches the maximum urethra pressure.

In the embodiment shown in FIG. 2, a decreased thickness is formed as a first semi-circumferential groove **114** near a proximal end of the balloon **110** and/or as a second semi-circumferential groove **116** near a distal end of the balloon **110**. The grooves **114**, **116** can have any cross-sectional shape, including, trapezoidal, triangular, square, or rectangle, for example. Because rubber, plastic, and silicone materials tear well with thinner cuts, a relatively triangular shape or one with a narrow bottom can be an exemplary configuration. To make sure that the entire balloon **110** of the illustrated embodiment does not completely tear away from the fluid drainage lumen **120**, both grooves **114**, **116** do not extend around the entire circumference of the balloon **110**. As shown to the left of the proximal groove **116** in FIG. 2, the groove **116** is not present on at least an arc portion **118** of the circumference of the balloon **110**. The arc portion is defined to be sufficiently large so that, when the catheter **100** is removed from the patient, the balloon **110** cannot tear away entirely from the catheter **100** (and create the disadvantageous fragmentation situation as set forth above). The illustrated balloon safety valve **112** is, therefore, fashioned to keep the balloon **110** in one piece after breaking and remain firmly connected to the catheter **100** to insure that no piece of the balloon **110** will be left inside the patient after actuation of the balloon safety valve **112**. Alternatively, the groove can be along the length of the balloon parallel to the axis of the catheter. This groove can be made by skiving the balloon after attaching to the catheter or by skiving the balloon as it is formed during extrusion or dip molding. In this embodiment, when the pressure exceeds a predetermined limit, the balloon splits along the groove without releasing fragments.

It is noted that the balloon **110** is inflated through an inflation lumen **130** having a proximal opening, typically formed by one end of a luer connector (see **260** in FIG. 3). The illustrated end is connected to a non-illustrated inflation device, for example, a distal end of a syringe for inflation of the balloon **110**.

In this first embodiment, the balloon can be of an elastomer, rubber, silicone, or plastic, for example. Once the balloon breaks, the catheter is useless and must be discarded. Because the balloon **110** in this embodiment will break inside the patient, it should be inflated with a bio-safe fluid to prevent unwanted air, gas, or bio-unsafe fluid from entering the patient. In certain circumstances where balloon catheters are used, air or gas will not injure the patient if let out into the patient's body cavity. In such circumstances, the inflating fluid can be air under pressure, for example.

Maximum urethra pressure can also be tailored to the individual patient. Based upon a urethral pressure-measuring

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device, the patient's maximum urethra pressure can be measured before the catheter **100** is placed therein. A set of catheters **100** having different safety valve breaking constants can be available to the physician and, after estimating or calculating or knowing the patient's maximum urethra pressure, the physician can select the catheter **100** having a safety valve breaking constant slightly or substantially smaller than the patient's maximum urethra pressure. Accordingly, if the pressure in the balloon **110** approaches the patient's maximum urethra pressure for any reason, whether it is due to over-inflation, improper placement, and/or premature removal, the balloon **110** is guaranteed to break prior to the patient's lumen (in particular, the patient's urethra) and, therefore, prior to causing injury.

A second embodiment of the one-use breaking safety valve of a pressure-limiting balloon catheter **200** is shown in FIG. 3. The catheter **200** has a fluid drainage lumen **220**, a balloon inflation lumen **230**, and a secondary lumen **240**.

The fluid drainage lumen **220** is connected fluidically to the body cavity (i.e., the bladder **30**) for draining fluid from the body cavity.

The secondary lumen **240** can be used for any purpose, for example, for housing the radiation line that will supply energy to the radiation coil **2**. It can also be used for injecting fluid into any distal part of the catheter **200** or even the body cavity itself.

The balloon inflation lumen **230** begins at a proximal end with an inflating connector **260** that, in an exemplary embodiment, is one part of a luer connector. The balloon inflation lumen **230** continues through the body of the catheter **200** all the way to the balloon **110** and is fluidically connected to the interior of the balloon **110**.

Alternatively or additionally, the balloon safety valve is fluidically connected to the balloon inflation lumen **230**. In a second embodiment of the safety valve **212**, the valve **212** is formed integrally with the balloon inflation lumen **230** and is set to open into the environment (instead of into the patient) if the maximum urethra pressure is exceeded in the balloon **110** or the balloon inflation lumen **230**. Alternatively and not illustrated, the valve **212** is formed integrally with the balloon inflation lumen **230** and is set to open into the drainage lumen **220** if the maximum urethra pressure is exceeded in the balloon **110** or the balloon inflation lumen **230**. A further alternative includes opening both into the environment and into the drainage lumen **220**. Because this safety valve **212** is located near or at the balloon inflation port **260** in this configuration, fluid used to inflate the balloon will not enter the patient when the valve **212** opens.

The safety valve **212** in the second embodiment can merely be a narrowing of the distance between the balloon inflation lumen **230** and the outer surface **250** of the catheter **220**. In FIG. 3, the valve **212** has a rectangular cross-section and extends away from the balloon inflation lumen **230**. As shown in FIGS. 4, 5, and 6, respectively, the cross-section can be triangular (peaked or pyramidal in three-dimensions), curved (circular or cylindrical in three-dimensions), or trapezoidal (frusto-conical or bar-shaped in three-dimensions). The cross-sections are shown in FIGS. 3 to 7 with the narrowing emanating from the balloon inflation lumen **230** outward. As an alternative, the narrowing can begin on the outer surface of the catheter and extend inwards towards the balloon inflation lumen **230**. A further alternative can have the narrowing extend from both the inner lumen **230** and the outer surface of the catheter.

The cross-sections illustrated are merely exemplary. What is important is that the thickness  $t$  between the bottom **213** of the valve **212** and the outer surface **250** of the catheter **220** in

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comparison to the thickness  $T$  of the catheter body over the remainder of the balloon inflation lumen **230**. An enlarged view of this thickness comparison is illustrated in FIG. 7. As long as the thickness  $t$  is smaller than the thickness  $T$  ( $t < T$ ), and as long as the force  $F_b$  required to break the balloon is greater than the force  $F_{sv}$  required to break the portion **213** of the safety valve **212** ( $F_b > F_{sv}$ ), then the portion **213** of the safety valve **212** is virtually guaranteed to break every time pressure exerting a force  $F$  in the balloon inflation lumen **230** is greater than the force  $F_{sv}$  required to break the safety valve ( $F_{sv} > F$ ).

Based upon this analysis, the force  $F_{sv}$  required to break the safety valve can be tuned to whatever a patient needs or a physician desires and different sized valves can be available for any procedure and provided in the form of a kit. Whether a standard maximum urethra pressure is used or a patient-specific maximum urethra pressure is measured and used, experiments can be conducted prior to use on a patient on various catheter thicknesses  $t$  to determine the pressure needed to break the portion **213** of the safety valve **212**. For example, ten different maximum urethra pressures can be known as desirable set points and the thicknesses  $t$  can be varied such that pressure required to break the ten thicknesses correspond to the ten set point pressures. If, then, ten catheters are placed in such a kit, each having one of the ten thicknesses, then the physician has a range of 10 maximum urethra pressure values to use with the patient.

Although FIGS. 3 to 7 show indentations into the wall of the catheter, the indentation can be in the form of a through-hole entirely through the wall of the catheter communicating with the outside of the catheter over which is placed a sleeve. Depending upon the pressure in the inflation lumen, fluid can leak through the hole and lift up the sleeve and leak to atmosphere therefrom. Pressure is controlled in this embodiment by the modulus of the sleeve material. A harder sleeve that fits snugly on the catheter will not allow leakage at low pressure. Alternatively, a softer rubbery sleeve would lift up easily to release high pressure fluid.

The safety valve **212** of the second embodiment need not be confined to the body of the catheter **200**. Instead, the inflating connector **260** can, itself, be equipped with the pressure relief valve **212**. Alternatively, a non-illustrated modular attachment containing the safety valve **212** can be attached to the inflating connector **260**. Such a modular valve attachment is removable and replaceable (such as through a conventional luer or even a screw-threaded connection). Accordingly, as long as the catheter **200** can still be used after the valve **212** actuates (breaks), the used modular valve attachment can be replaced with a new attachment. The converse is also true for reuse of the attachment if the catheter **200** breaks and the valve of the attachment remains unbroken. A downstream end of the modular valve attachment (e.g., shaped as part of a luer connector) is attached removably to an upstream end of the inflating connector **260** and the upstream end of the modular valve attachment is to be connected to the balloon inflation device, which is commonly a syringe. The upstream end of the modular valve attachment is, likewise, part of a luer connector for easy connection to standard medical devices. In such a configuration, the safety valve **212**, **312** of the present invention can be entirely separate from the catheter **200**, **300** and, therefore, form a retrofitting device for attachment to any luer connector part present on conventional catheters.

As an alternative to the one-use breaking safety valve of the second embodiment, a multi-use pressure valve can be used. This third embodiment of the pressure-limiting balloon catheter **300** is illustrated in FIG. 8. The catheter **300** can be the same as the catheter **200** in FIG. 3 except for the portion

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illustrated in FIG. 8. Instead of having a narrowing thickness  $t$  of the lumen wall, the valve portion **313** extends entirely to the environment (and/or into the drainage lumen **220**). However, a one-way valve **314** (shown only diagrammatically in FIG. 8) is attached to the open end of the valve portion **313** and is secured to the outer surface **250** of the catheter **300** to close off the open end of the valve portion **313**. The one-way valve **314** can be secured directly to the outer surface **250** (e.g., with an adhesive), or a connector **315** (e.g., a threaded cap) can secure the one-way valve **314** to the open end of the valve portion **313**. Regardless of the configuration, the one-way valve **314** includes a device that does not permit fluid from exiting the lumen **230** until a given resistance  $R$  is overcome. This given resistance  $R$  can be selectable by the physician depending upon the one-way valve that is chosen for use if a set of one-way valves having different resistances  $R$  are available for use by the physician. Just like the second embodiment, the resistance  $R$  can be set to correspond to desired maximum urethra pressure values. Therefore, when used, the fluid exits the one-way valve **314** into the environment well before the patient's maximum urethra pressure is exceeded by the balloon.

The one-way valve **314** can be a mechanical one-way valve. Additionally, the one-way valve **314** can be a material having a tear strength corresponding to a desired set of resistances  $R$ . The material can be a fluid-tight fabric, a rubber, a plastic, or silicone different from the material making up the catheter. The material can even be a rubber, plastic, or silicone the same as the material making up the catheter but having a reduced thickness  $t$  than the thickness  $T$  of the catheter. Alternatively, the one-way valve **314** can be a slit valve. Various exemplary embodiments of such a valve can be found in U.S. Pat. No. 4,995,863 to Nichols et al., which is hereby incorporated herein by reference in its entirety.

It can also be appreciated that the pressure release (or relief) valve can be a conventional pressure release valve comprised of a housing with a lumen, a ball, and a spring within the lumen wherein the spring presses the ball against a defined opening. When pressure on the ball exceeds the force of the spring, the ball moves away from the defined opening and fluid moves around the ball and vents to atmosphere. By controlling tension on the spring, the pressure at which the valve releases pressure can be controlled. It can also be appreciated that the pressure release valve can be coupled to a Luer connector, which can be coupled to a one-way check valve that can be used to inflate the balloon as is often used in conventional urinary drainage catheters.

Because the safety valve **212**, **312** is located at the proximal end of the catheter **200**, **300**, the distal end of the catheter **200**, **300** can take the form of a distal end of a conventional balloon catheter **2**, **3**, **4**, **5**. Alternatively, the distal end shown in FIG. 2 can also be used for redundant over-pressure protection.

In another exemplary embodiment of the present invention, FIGS. 9 to 18 illustrate alternatives to the elastomeric balloon described above. In particular, the above elastomeric balloon is replaced by a thin walled, pre-formed, fixed diameter balloon **1010** that inflates with virtually no pressure and withstands pressures between approximately 0.2 atmospheres (2.9 psi) and 0.5 atmospheres (7.35 psi), the latter of which is approximately equal to the maximum urethra pressure, without an appreciable increase in diameter. Examples of such balloon materials and thicknesses are used in the medical field already, such as those used in angioplasty. Other exemplary materials can be those used in commercial (party) balloons, for example, MYLAR®, or similar materials such as nylon, PTA, PTFE, polyethylene and polyurethane, for example. In FIGS. 9 and 13, the balloon **1010** is shown in a

spherical shape. However, the balloon **1010** can be, for example, cylindrical with flat or conically tapering ends.

The inflation balloon **1010** can be formed by heating a tubular material within a mold or by heat-sealing thin sheets to one another (e.g., party balloons have two sheets). One example of the relatively non-compliant, thin-walled balloon **1010** of the present invention is formed using a blow-molding process. In the blow-molding process, a thermoplastic material such as nylon, polyurethane, or polycarbonate is extruded or formed into a hollow, tube-like shape (parison) and is subsequently heated and pressurized, usually with air, inside a hollow mold having a shape to form the final outer dimensions of the balloon. An example of the blow molded product is the common plastic soda or water bottle containers.

One exemplary, but not limiting, process to form the zero-pressure balloon of the present invention is described with respect to FIG. **11** and includes, in Step **1110**, cutting a relatively short piece of “parison” tubing that is formed using standard “air-mandrel” extrusion techniques. In Step **1120**, one end of the tubing is sealed. The center portion of the tubing is placed in a hollow mold, leaving both ends extending outside of the mold in Step **1130**. The center of the tubing is heated in Step **1140** with a hot stream of air through a small hole in the center of the mold for a few seconds to soften the tubing walls within the mold. The inside of the tubing is pressurized with a fluid, e.g., air, in Step **1150** to stretch the tubing walls to conform to the inside dimensions of the mold. After a short cooling period, an additional stretch of the formed balloon is done in Step **1160** by pulling on the (external) parison and, after a second “blowing” in the same mold in Step **1170**, is used to create a very thin-walled balloon (much less than 0.001 inches, typically, based upon the parison wall thickness and the final balloon diameter). The extra (unblown) parison tubing is then cut off from both ends in Step **1180**, leaving the thin walled, relatively supple balloon and its “legs” to be mounted to the catheter as described below.

This exemplary process can be used to create thin, non-compliant balloons for “angioplasty” of blood vessels at pressures exceeding 12 atmospheres of pressure, for example. Although these pressures are not necessary in the present application, it is witness to the fact that very strong thin-walled balloons can result from the above manufacturing process.

The present invention’s thin, non-compliant zero-pressure balloon can be attached to the drainage catheter in a number of ways. In a first exemplary attachment embodiment, reference is made to the process of FIG. **12**, the slit valve of FIG. **13**, and the removable balloon of FIG. **16**.

In an exemplary embodiment, each of the distal and proximal legs of the balloon **1010** manufactured according to the process of FIG. **12** is attached to the distal end of the drainage catheter using standard (e.g., FDA-approved) cements or by heat fusing the two pieces together. The non-compliant, thin-walled balloon is dimensioned to envelop the “slit valves” shown, for example, in FIG. **13**, as an exemplary configuration of the invention. The balloon’s thin walls allow folding of the balloon without a significant increase in the catheter outer diameter for ease in catheter insertion.

Exemplary embodiments of the internal balloon valve **1012** according to the invention are illustrated in FIGS. **13**, **14**, and **15**. This internal balloon valve **1012** is formed by cutting the wall of the drainage lumen **1120** at the portion of the catheter within the balloon **1010**. The slit can be a single cut or a plurality of cuts. Some exemplary slit valves other than those shown are described in U.S. Pat. No. 4,995,863 to Nichols et al., all of which can be utilized for the present invention. The slit-opening pressure, therefore, can be regu-

lated by adjusting the number, length and spacing of the slit(s) and the thickness of the drainage lumen wall **1122**. For example, the length and orientation of the slit(s) **1012** determines the pressure at which it/they will open and drain the balloon inflation lumen **1130**. In one particular embodiment shown in FIG. **15**, the slits **1124** are cut through the elastomeric walls in a way that results in a wedge-shaped cross-section. With this wedge shape, fluid within the balloon can drain under pressure easily. The wedge can be increasing or decreasing. With the former, the edges are chamfered towards one another from the central axis of the balloon toward the exterior thereof (e.g., illustrated in FIG. **15**) and, with the latter, the edges are chamfered towards one another from the exterior of the balloon toward the central axis.

In another exemplary embodiment, a non-illustrated, thin-walled slitted sleeve can be disposed over the portion of the drainage catheter wall **1122** within the balloon **1010** and covering a throughbore fluidically connecting the interior of the balloon **1010** to the interior of the drainage lumen **1120**. As such, pressure within the balloon **1010** will open the slit(s) of the sleeve, thereby fluidically connecting the balloon **1010** interior with the drainage lumen **1120** to transfer fluid in the balloon **1010** to the drainage lumen **1120**. Each of these exemplary balloon configurations entirely prevents damage caused by improper inflation or premature removal.

Alternatively, the balloon wall itself could be modified to burst at a particular pressure to release the inflation media. This weakened section could be created by mechanical, chemical, or thermal treatment for example. Mechanical measures may be accomplished by scratching the surface and, thus, thinning the balloon wall in a particular section to cause it to burst at a pre-determined pressure or actually slicing or punching a hole in the wall and covering the area with a thinner, weaker film of material which will tear at a predetermined pressure lower than the rest of the balloon. Likewise, a chemical solvent could be applied to create the same effect as the mechanical device above by making chemical changes to the plastic molecular structure of the balloon wall and, thereby, weakening a desired section of the balloon wall. Weakening a section of the wall by heat to thereby re-orient its molecular structure (much like softening by annealing) is also possible. Therefore, the preferential tearing of the balloon wall at a predetermined internal pressure can be effected in a number of ways as exemplified by, but not limited to, the methods described above.

A second exemplary, but not limiting, process to attach the zero-pressure balloon of the present invention to the safety catheter **1600** of the present invention, which can be used with or without the slit valves, is described with respect to FIGS. **12** and **16** and includes, in Step **1210**, assembling a first proximal leg **1620** of the balloon **1610** over the distal end of the drainage catheter shaft **1630** in an “inverted” direction (open end toward the balloon interior as shown in FIG. **16**). This inverted connection is accomplished with a mechanical release that can be formed, for example, merely by using the shape of the proximal leg **1620** of the balloon **1610** or by using a separate compression device, such as an elastic band, or by using adhesives that removably connect the proximal leg **1620** to the drainage catheter shaft **1630**. In a compression only example, the proximal balloon seal is, thereby, formed by the force of the “inverted” relatively non-compliant proximal leg **1620** being extended over and around the distal end of the flexible drainage catheter shaft **1630** by, for example, stretching the material of the drainage catheter shaft **1630** (e.g., silicone) to reduce its outer diameter. The other, distal leg **1640** of the balloon **1610** can, then, be attached in Step **1220** using cements (as in the first example above) or by heat

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fusion. It is noted that, while attachment is shown and described in an inverted orientation for the proximal leg **1620** and in a non-inverted orientation for the distal leg **1640**, these are not the only possible orientations for each and can be assembled in any combination of inverted and non-inverted orientations. For example, the distal leg **1640** can, as the proximal leg **1620**, be attached in an inverted direction not illustrated in FIG. 16.

To further aid in balloon assembly and catheter deflation and insertion, the outer diameter of the catheter **1600** under the balloon **1610**, as well as the inner diameter of the distal balloon leg **1640**, can be reduced as compared with the outer diameter of the drainage catheter shaft **1630**, which configuration is shown in FIGS. 16 to 19. The reduced-diameter portion of the catheter **1600** is referred herein as the distal tip portion **1650** and extends from the distal end of the drainage catheter shaft **1630** at least to the distal end of the distal balloon leg **1640**. As shown, the distal tip **5** (distal of the balloon **1610**) also can have the same reduced diameter (or can be reduced further or increased larger as desired). Thus, if the outer diameter of the distal tip portion **1650** is reduced immediately distal of the proximal balloon seal **1620**, any predetermined pull force will stretch the catheter shaft **1630**, thereby reducing the outer diameter of the catheter shaft **1630** at the proximal balloon seal and allowing the proximal balloon leg **1620** to slide or peel distally and deflate the balloon quickly, at which time all fluid is released therefrom into the bladder or urethra, for example. It is envisioned that the proximal balloon leg **1620** can be mounted with the balloon leg **1620** in a non-inverted or "straight" position if desired with similar results. However, in such a configuration, sliding of the proximal leg **1620** over the distal end of the catheter shaft **1630** may be more resistant to a pulling force on the exposed proximal end of the catheter shaft **1630** but the slight incursion of the balloon-filling fluid can be used to lubricate this connection and, therefore, the resistance to pulling decreases.

With a zero-pressure configuration as described and referred to herein, the balloon **1010**, **1610** is under zero-pressure or low pressure. Thus, the inflation device (e.g., a syringe) need not be configured to deliver pressure much above the low pressure range described above. Mere presence of the filling liquid in the balloon, makes the balloon large enough to resist and prevent movement of the balloon into the urethra and out of the bladder without having an internal, high pressure. As such, when inserted improperly in the urethra, the balloon will simply not inflate because there is no physical space for the balloon to expand and because the inflation pressure remains beneath the urethral damaging pressure threshold. If the inflation device is configured for low pressure, even maximum delivered pressure to the balloon will be insufficient to inflate the balloon within the urethra, thereby preventing any possibility of balloon inflation inside the urethra.

In the other case where the balloon is inflated properly within the bladder but the catheter is improperly removed out from the patient without deflating the balloon, safety devices of the invention prevent tearing of the urethra upon exit. Any combination of the internal balloon valve **1012** (e.g., the slit valve of FIG. 13 formed through the wall of a portion of the drainage lumen **1120** located inside the balloon **1010**, **1610**) and the removable proximal balloon seal **1620** can be used; one or both can be employed to provide the safety features of the invention. In operation, when a predetermined inflation pressure is reached, the internal balloon valve **1012** opens and any fluid in the balloon **1010**, **1610** is emptied through the drainage lumen **1120** into the bladder (distal) and/or the exter-

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nal drain bag (proximal), the latter of which is not illustrated. As set forth above, the point at which pressure causes the internal balloon valve **1012** to open is defined to be less than the pressure needed to damage the urethra when a fully inflated prior-art balloon catheter is improperly removed as described herein. In a low-pressure state, in which the balloon **1010**, **1610** is filled with a fluid (either liquid or gas), there is not enough pressure to force open the internal balloon valve **1012** and permit exit of the fluid out from the balloon **1010**, **1610**. In a higher-pressure state (below urethra damage pressure), in contrast, pressure exerted on the fluid is sufficient to open the internal balloon valve **1012**, thus permitting the fluid to quickly drain out of the balloon **1010**, **1610** and into the drainage lumen **1120**.

In a situation where the balloon **1010**, **1610** is in the urethra and inflation is attempted, pressure exerted by the surrounding urethral wall on the inflating balloon **1010**, **1610** will cause the internal balloon valve **1012** to open up well before the balloon **1010**, **1610** could inflate. Thus, the balloon inflation fluid will, instead of filling the balloon **1010**, **1610**, exit directly into the drainage lumen **1120**. In an alternative embodiment, the fluid used can be colored to contrast with urine (or any other fluid that is envisioned to pass through the drainage lumen). Thus, if the balloon **1010**, **1610** is inserted only into the urethra and inflation is attempted, the inflating fluid will immediately exit into the drainage lumen and enter the exterior (non-illustrated) drain bag. Thus, within a few seconds, the technician will know if the balloon **1010**, **1610** did not enter the bladder and inflate therein properly by seeing the colored inflation fluid in the drain bag. In such a situation, the technician needs to only insert the catheter further into the urethra and attempt inflation again. The absence of further colored inflation fluid in the drain bag indicates that correct balloon inflation occurred.

In the other situation where the balloon **1010**, **1610** is inflated within the bladder and the catheter **100** is pulled out from the bladder without deflating the balloon **1010**, **1610**, pressure exerted by the urethrovesical junction **11** upon the inflated balloon **1010**, **1610** will cause the valve **1012** to open up quickly and cause fluid flow into the drainage lumen **1120** before injury occurs to the junction **11** or the urethra. If, in such a situation, the catheter is also equipped with the removable balloon end (e.g., proximal end **1620**), then, as the removable balloon end is peeling off, the slit valve opens up to relieve pressure either before or at the same time the peeling off occurs. This allows the inflation fluid to exit even faster than if just the valve **1012** is present.

FIGS. 16 to 18 illustrate an exemplary embodiment of the inventive catheter **1600** with the everting removable balloon **1610**. These figures illustrate the situation where the balloon **1610** is inflated within the bladder and, as indicated by the pull arrow, the catheter **1600** is pulled out from the bladder without deflating the balloon **1610**. Here, the distal seal **1640** of the balloon **1610** is fixed to the distal tip portion **1650** of the catheter **1600**, which tip **5** has a reduced outer diameter as compared to the drainage catheter shaft **1630**, and the proximal seal **1620** is removably attached (e.g., with a compression seal) to the drainage catheter shaft **1630**. The pulling force causes the drainage catheter shaft **1630** to move in the proximal direction out of the urethra and, thereby, compress the proximal side of the inflated balloon **1610** against the urethrovesical junction **11**. As the catheter shaft **1630** moves proximally, the force on the proximal seal **1620** increases until the seal **1620** breaks free of the catheter shaft **1630**, referred to herein as the breakaway point. FIG. 17 illustrates the now partially inflated balloon **1610** just after the breakaway point. Because the diameter of the distal tip portion

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1650 is reduced in comparison to the distal end of the catheter shaft 1630, a gap opens up between the inner diameter of the proximal seal portion of the balloon 1610 and the outer diameter of the distal tip portion 1650. This gap allows the inflating fluid to exit the balloon 1610 quickly into one or both of the urethra and the bladder before injury occurs to the junction 11 or to the urethra. As the central portion of the balloon 1610 is still larger than the urethral opening of the junction 11, the friction and force imparted on the balloon 1610 causes the balloon 1610 to roll over itself, i.e., evert, until it is entirely everted as shown in FIG. 18. At this time, all of the inflating fluid is either in the urethra and/or in the bladder.

In an exemplary embodiment of the removable proximal balloon seal 1620, a pulling force in a range of 1 to 15 pounds will cause the proximal balloon seal 1620 to pull free and allow eversion of the balloon 1610, i.e., the breakaway point. In another exemplary embodiment, the range of force required to meet the breakaway point is between 1 and 5 pounds, in particular, between 1.5 and 2 pounds.

With regard to additional exemplary embodiments of self-deflating or automatically deflating balloon catheters according to the invention, FIGS. 19 and 20 are provided to illustrate the construction and processes for manufacturing prior art urinary catheters, also referred to as Foley catheters. Although prior art urinary catheters are used herein to assist in the understanding of the exemplary embodiments of urinary balloon catheters according to the invention, neither are used herein to imply that the invention is solely applicable to urinary-type catheters. Instead, the technology described herein can be applied to any balloon catheter.

FIG. 19 shows the balloon portion of the prior art catheter 1900 with the balloon in its uninflated state. An annular inner lumen wall 1910 (red) defines therein a drainage lumen 1912. At one circumferential longitudinal extent about the inner lumen wall 1910, an inflation lumen wall 1920 (orange) defines an inflation lumen 1922 and a balloon inflation port 1924 fluidically connected to the inflation lumen 1922; in standard urinary catheters, there is only one inflation lumen 1922 and one inflation port 1924. The views of FIGS. 19 and 20 show a cross-section through the inflation lumen 1922 and inflation port 1924. If the inflation lumen 1922 extended all of the way through the catheter 1900 to its distal end (to the left of FIGS. 19 and 20), then the balloon could not inflate as all inflation liquid would exit the distal end. Therefore, in order to allow inflation of the balloon, a lumen plug 1926 (black) closes the inflation lumen 1922 distal of the inflation port 1924. In this exemplary illustration, the lumen plug 1926 starts at a position distal of the inflation port 1924 at the inflation lumen 1922.

About the inner lumen and inflation lumen walls 1910, 1920 around the inflation port 1924 is a tube of material that forms the balloon interior wall 1930 (green). The tube forming the balloon interior wall 1930 is fluid-tightly sealed against the respective inner walls 1910, 1920 only at the proximal and distal ends of the tube. Accordingly, a pocket is formed therebetween. An outer wall 1940 (yellow) covers all of the walls 1910, 1920, 1926, 1930 and does so in what has referred to herein as a fluid-tight manner, meaning that any fluid used to blow up the balloon through the inflation lumen 1922 and the inflation port 1924 will not exit the catheter 1900 through the fluid-tight connection. FIG. 20 illustrates the fluid inflating the balloon (indicated with dashed arrows). Because at least the balloon interior wall 1930 and the outer wall 1940 are elastomeric, pressure exerted by the inflating fluid 2000 against these walls will cause them to balloon outwards as, for example, shown in FIG. 20. When the non-illustrated proximal end of the catheter 1900 is sealed with the fluid 2000

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therein (e.g., with at least a part of a luer connector as shown in FIG. 3), the catheter 1900 will remain in the shape shown in FIG. 20.

As set forth above, the balloon 2010 of a urinary catheter should be inflated only when in the bladder 2020. FIG. 20 shows the catheter 1900 correctly inflated in the bladder 2020 and then, if needed, pulled proximally so that the inflated balloon 2010 rests against and substantially seals off the urethra 2030 from the interior of the bladder 2020. "Substantially," as used in this regard means that most or all of the urine in the bladder 2020 will drain through the drain lumen 1912 and will not pass around the inflated balloon 2010 more than is typical and/or required for correctly implanted urinary catheters. It is known that an insubstantial amount of urine will pass the balloon 2010 and, advantageously, lubricate the urethra 2030 but will not leak out the end of the urethra as muscles in the various anatomy of males and females will seal the end with sufficient force to prevent significant leakage.

Even though each of the walls is shown in different colors herein, the different colors do not imply that the respective walls must be made of different materials. These colors are used merely for clarity purposes to show the individual parts of the prior art and inventive catheters described herein. As will be described in further detail below, most of the different colored walls actually are, in standard urinary catheters, made of the same material. Some of the biocompatible materials used for standard Foley catheters include latex (natural or synthetic), silicone rubber, and thermoplastic elastomers (TPEs) including styrenic block copolymers, polyolefin blends, elastomeric alloys (TPE-v or TPV), thermoplastic polyurethanes, thermoplastic copolyester, and thermoplastic polyamides.

One exemplary process for creating the prior art urinary catheters starts with a dual lumen extrusion of latex. The dual lumen, therefore, already includes both the drainage lumen 1912 and the inflation lumen 1922. Both lumen 1912, 1922, however, are extruded without obstruction and without radial ports. Therefore, in order to have the inflation port 1924, a radial hole is created from the outside surface inwards to the inflation lumen. Sealing off of the distal end of the inflation lumen 1922 is performed in a subsequent step. The tube making up the inner balloon wall 1930 is slid over the distal end of the multi-lumen extrusion 1910, 1920 to cover the inflation port and is fluid-tightly sealed to the inner multi-lumen extrusion at both ends of the tube but not in the intermediate portion. This tube can be made of latex as well and, therefore, can be secured to the latex multi-lumen extrusion in any known way to bond latex in a fluid-tight manner. At this point, the entire sub-assembly is dipped into latex in its liquid form to create the outer wall 1940. The latex is allowed to enter at least a portion of the distal end of the inflation lumen 1922 but not so far as to block the inflation port 1924. When the latex cures, the balloon 2010 is fluid tight and can only be fluidically connected to the environment through the non-illustrated, proximal-most opening of the inflation port, which is fluidically connected to the inflation lumen 1922. In this process, the inner wall 1910, the inflation lumen wall 1920, the plug 1926, the balloon interior wall 1930, and the outer wall 1940 are all made of the same latex material and, therefore, together, form a very securely water-tight balloon 2010.

As set forth above, all prior art balloon catheters are designed to deflate only when actively deflated, either by a syringe similar to the one that inflated it or by surgery after the physician diagnoses the balloon as not being able to deflate, in which circumstance, a procedure to pop the balloon surgically is required.



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Described above are various embodiments of self-deflating or automatically deflating catheters according to the invention. FIGS. 21 to 33 illustrate automatically deflating, stretch-valve balloon catheters in still other exemplary embodiments of the present invention. FIGS. 21 to 23 show a first exemplary embodiment of a stretch-valve balloon catheter 2100 according to the invention, FIG. 21 illustrating the balloon portion of the inventive catheter 2100 with the balloon in its uninflated state. An annular inner lumen wall 2110 (red) defines therein a drainage lumen 2112. At one or more circumferential longitudinal extents about the inner lumen wall 2110, an inflation lumen wall 2120 (orange) defines an inflation lumen 2122 and a balloon inflation port 2124 fluidically connected to the inflation lumen 2122; in the inventive catheter, there can be more than one inflation lumen 2122 and corresponding inflation port 2124 even though only one is shown herein. Accordingly, the views of FIGS. 21 to 23 show a cross-section through the single inflation lumen 2122 and single inflation port 2124. A lumen plug 2126 (black) closes the inflation lumen 2122 distal of the inflation port 2124. In this exemplary illustration, the lumen plug 2126 starts at a position distal of the inflation port 2124 at the inflation lumen 2122. This configuration is only exemplary and can start at the inflation port 2124 or anywhere distal thereof.

About the inner lumen and inflation lumen walls 2110, 2120 around the inflation port 2124 is a tube of material that forms the balloon interior wall 2130 (green). The tube of the balloon interior wall 2130 is fluid-tightly sealed against the respective inner walls 2110, 2120 only at the proximal and distal ends of the tube. Accordingly, a pocket is formed therebetween. An outer wall 2140 (yellow) covers all of the walls 2110, 2120, 2126, 2130 in a fluid-tight manner. FIG. 21 illustrates the fluid about to inflate the balloon (indicated with dashed arrows). Because at least the balloon interior wall 2130 and the outer wall 2140 are elastomeric, pressure exerted by the inflating fluid 2200 against these walls will cause them to balloon outwards as, for example, shown in FIG. 22. When the non-illustrated proximal end of the catheter 2100 is sealed with the fluid 2200 therein (e.g., with at least a part of a luer connector as shown in FIG. 3), the catheter 2100 will remain in the shape shown in FIG. 22.

FIG. 22 shows the catheter 2100 correctly inflated in the bladder 2020 and then, if needed, pulled proximally so that the inflated balloon 2210 rests against and substantially seals off the urethra 2030 from the interior of the bladder 2020.

The stretch-valve of the exemplary embodiment of FIGS. 21 to 23 has three different aspects. The first is a hollow, stretch-valve tube 2220 that is disposed in the inflation lumen 2122 to not hinder inflation of the balloon 2210 with the fluid 2200. While the diameter of the stretch-valve tube 2220 can be any size that accommodates unhindered fluid flow through the inflation lumen 2122, one exemplary inner diameter of the stretch-valve tube 2220 is substantially equal to the diameter of the inflation lumen 2122 and the outer diameter of the stretch-valve tube 2220 is just slightly larger than the diameter of the inflation lumen 2122 (e.g., the wall thickness of the tube can be between 0.05 mm and 0.2 mm). The proximal end of the stretch-valve tube 2220 in this exemplary embodiment is proximal of a proximal end of the balloon inner wall 2130. The distal end of the stretch-valve tube 2220 is somewhere near the proximal end of the balloon inner wall 2130; the distal end can be proximal, at, or distal to the proximal end of the balloon inner wall 2130 and selection of this position is dependent upon the amount of stretch S required to actuate the stretch-valve of the inventive catheter 2100 as described below. In FIG. 22, the distal end of the stretch-valve tube 2220 is shown at the proximal end of the balloon inner wall 2130.

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Two ports are formed proximal of the balloon 2210. A proximal port (purple) 2150 is formed through the outer wall 2140 and through the inflation lumen wall 2020 overlapping at least a portion of the proximal end of the stretch-valve tube 2220. In this manner, a portion of the outer surface of the proximal end of the stretch-valve tube 2220 at the proximal port 2150 is exposed to the environment but there is no fluid communication with the inflation lumen 2122 and the proximal port 2150. A distal port (white) 2160 is formed through the outer wall 2140 and through the inflation lumen wall 2020 overlapping at least a portion of the distal end of the stretch-valve tube 2220. In this manner, a portion of the outer surface of the distal end of the stretch-valve tube 2220 at the distal port 2160 is exposed to the environment but there is no fluid communication from the inflation lumen 2122 to the distal port 2160. To secure the stretch-valve tube 2220 in the catheter 2100, the proximal port 2150 is filled with a material that fixes the proximal end of the stretch-valve tube 2220 to at least one of the outer wall 2140 and the inflation lumen wall 2020. In one exemplary embodiment, an adhesive bonds the proximal end of the stretch-valve tube 2220 to both the outer wall 2140 and the inflation lumen wall 2120.

In such a configuration, therefore, any proximal movement of the catheter 2100 at or proximal of the proximal port 2150 will also move the stretch-valve tube 2220 proximally; in other words, the distal end of the stretch-valve tube 2220 can slide S within the inflation lumen 2122 in a proximal direction. FIG. 23 illustrates how the slide-valve of the invention operates when the proximal end of the catheter 2100 is pulled with a force that is no greater than just before injury would occur to the urethrovaginal junction or the urethra if the catheter 2100 was still inflated when the force was imparted. In an exemplary embodiment of the stretch valve of FIGS. 21 to 23, a pulling force in a range of 1 to 15 pounds will cause the stretch-valve tube 2220 to slide proximally S to place the distal end of the stretch-valve tube 2220 just proximal of the distal port 2160, i.e., the deflation point of the stretch-valve shown in FIG. 23. In another exemplary embodiment, the range of force required to meet the deflation point is between 1 and 5 pounds, in particular, between 1.5 and 2 pounds.

As can be seen in FIG. 23, when the deflation point of the stretch-valve is reached, the interior of the balloon 2210 becomes fluidically connected to the distal port 2160. Because the distal port 2160 is open to the environment (e.g., the interior of the bladder 2020) and due to the fact that the bladder is relatively unpressurized as compared to the balloon 2210, all internal pressure is released from the balloon 2210 to eject the inflating fluid 2200 into the bladder 2020 (depicted by dashed arrows), thereby causing the balloon 2210 to deflate rapidly (depicted by solid opposing arrows). It is noted that the distance X (see FIG. 22) between the inflation port 2124 and the distal port 2160 directly impacts the rate at which the balloon 2120 deflates. As such, reducing this distance X will increase the speed at which the balloon 2210 deflates. Also, the cross-sectional areas of the inflation port 2124, the inflation lumen 2122, and the distal port 2160 directly impact the rate at which the balloon 2220 deflates. Further, any changes in direction of the fluid can hinder the rate at which the balloon deflates. One way to speed up deflation can be to shape the distal port 2160 in the form of a non-illustrated funnel outwardly expanding from the inflation lumen 2122. Another way to speed up deflation is to have two or more inflation lumens 2122 about the circumference of the inner lumen wall 2110 and to have corresponding sets of a stretch-valve tube 2220, a proximal port 2150, and a distal port 2160 for each inflation lumen 2122.

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Still another possibility for rapidly deflating an inflated balloon is to drain the fluid 2200 into the drain lumen 2112 instead of the bladder. This exemplary embodiment is illustrated in FIGS. 24 to 26. FIG. 24 illustrates the balloon portion of the inventive catheter 2400 with the balloon in its uninflated state. An annular inner lumen wall 2410 (red) defines therein a drainage lumen 2412. At one or more circumferential longitudinal extents about the inner lumen wall 2410, an inflation lumen wall 2420 (orange) defines an inflation lumen 2422 and a balloon inflation port 2424 fluidically connected to the inflation lumen 2422; in the inventive catheter, there can be more than one inflation lumen 2422 and corresponding inflation port 2424 even though only one is shown herein. Accordingly, the views of FIGS. 24 to 26 show a cross-section through the single inflation lumen 2422 and single inflation port 2424. A lumen plug 2426 (black) closes the inflation lumen 2422 distal of the inflation port 2424. In this exemplary illustration, the lumen plug 2426 starts at a position distal of the inflation port 2424 at the inflation lumen 2422. This configuration is only exemplary and can start at the inflation port 2424 or anywhere distal thereof.

About the inner lumen and inflation lumen walls 2410, 2420 around the inflation port 2424 is a tube of material that forms the balloon interior wall 2430 (green). The tube of the balloon interior wall 2430 is fluid-tightly sealed against the respective inner walls 2410, 2420 only at the proximal and distal ends of the tube. Accordingly, a pocket is formed therebetween. An outer wall 2440 (yellow) covers all of the walls 2410, 2420, 2426, 2430 in a fluid-tight manner. FIG. 24 illustrates the fluid about to inflate the balloon (indicated with dashed arrows). Because at least the balloon interior wall 2430 and the outer wall 2440 are elastomeric, pressure exerted by the inflating fluid 2200 against these walls will cause them to balloon outwards as, for example, shown in FIG. 25. When the non-illustrated proximal end of the catheter 2400 is sealed with the fluid 2200 therein (e.g., with at least a part of a luer connector as shown in FIG. 3), the catheter 2400 will remain in the shape shown in FIG. 25.

FIG. 25 shows the catheter 2400 correctly inflated in the bladder 2020 and then, if needed, pulled proximally so that the inflated balloon 2510 rests against and substantially seals off the urethra 2030 from the interior of the bladder 2020.

The stretch-valve of the exemplary embodiment of FIGS. 24 to 26 has three different aspects. The first is a hollow, stretch-valve tube 2520 that is disposed in the inflation lumen 2422 to not hinder inflation of the balloon 2510 with the fluid 2200. While the diameter of the stretch-valve tube 2520 can be any size that accommodates unhindered fluid flow through the inflation lumen 2422, one exemplary inner diameter of the stretch-valve tube 2520 is substantially equal to the diameter of the inflation lumen 2422 and the outer diameter of the stretch-valve tube 2520 is just slightly larger than the diameter of the inflation lumen 2122 (e.g., the wall thickness of the tube can be between 0.05 mm and 0.2 mm). The proximal end of the stretch-valve tube 2520 in this exemplary embodiment is disposed proximal of a proximal end of the balloon inner wall 2430. The distal end of the stretch-valve tube 2520 is somewhere near the proximal end of the balloon inner wall 2430; the distal end can be proximal, at, or distal to the proximal end of the balloon inner wall 2430 and selection of this position is dependent upon the amount of stretch S required to actuate the stretch-valve of the inventive catheter 2400 as described below. In the exemplary embodiment of FIG. 25, the distal end of the stretch-valve tube 2520 is shown at proximal end of the balloon inner wall 2430. Two ports are formed, one proximal of the balloon 2510 and one proximal of the inflation port 2424. A proximal port (purple) 2450 is

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formed through the outer wall 2440 and through the inflation lumen wall 2420 to overlap at least a portion of the proximal end of the stretch-valve tube 2520. In this manner, a portion of the outer surface of the proximal end of the stretch-valve tube 2520 at the proximal port 2450 is exposed to the environment but there is no fluid communication between the inflation lumen 2422 and the proximal port 2450. A distal port (white) 2460 is formed through the inner lumen wall 2410 anywhere proximal of the inflation port 2424 to overlap at least a portion of the distal end of the stretch-valve tube 2520. In this manner, a portion of the outer surface of the distal end of the stretch-valve tube 2520 at the distal port 2460 is exposed to the drainage lumen 2412 but there is no fluid communication between the inflation lumen 2422 and the distal port 2460. To secure the stretch-valve tube 2520 in the catheter 2400, the proximal port 2450 is filled with a material that fixes the proximal end of the stretch-valve tube 2520 to at least one of the outer wall 2440 and the inflation lumen wall 2420. In one exemplary embodiment, an adhesive bonds the proximal end of the stretch-valve tube 2520 to both the outer wall 2440 and the inflation lumen wall 2420.

In such a configuration, therefore, any proximal movement of the catheter 2400 at or proximal to the proximal port 2450 will also move the stretch-valve tube 2520 proximally; in other words, the distal end of the stretch-valve tube 2520 can slide S within the inflation lumen 2422 in a proximal direction. FIG. 26 illustrates how the slide-valve of the invention operates when the proximal end of the catheter 2400 is pulled to a force that is no greater than just before injury would occur to the urethrovesical junction or the urethra if the catheter 2400 was still inflated when the force was imparted. In an exemplary embodiment of the stretch valve of FIGS. 24 to 26, a pulling force in a range of 1 to 15 pounds will cause the stretch-valve tube 2520 to slide proximally S to place the distal end of the stretch-valve tube 2520 just proximal of the distal port 2460, i.e., the deflation point of the stretch-valve shown in FIG. 26. In another exemplary embodiment, the range of force required to meet the deflation point is between 1 and 5 pounds, in particular, between 1.5 and 2 pounds.

As can be seen in FIG. 26, when the deflation point of the stretch-valve is reached, the interior of the balloon 2210 becomes fluidically connected to the distal port 2460. Because the distal port 2460 is open to the drainage lumen 2412 (which is open the interior of the bladder 2020 and the non-illustrated, proximal drainage bag) and due to the fact that the bladder is relatively unpressurized as compared to the balloon 2510, all internal pressure is released from the balloon 2510 to eject the inflating fluid 2200 into the drainage lumen 2412 (depicted by dashed arrows), thereby causing the balloon 2510 to deflate rapidly (depicted by solid opposing arrows). Again, it is noted that the distance X between the inflation port 2424 and the distal port 2460 (see FIG. 25) directly impacts the rate at which the balloon 2510 deflates. As such, having this distance X be smaller will increase the speed at which the balloon 2510 deflates. Also, the cross-sectional areas of the inflation port 2424, the inflation lumen 2422, and the distal port 2460 directly impact the rate at which the balloon 2120 deflates. Further, any changes in direction of the fluid can hinder the rate at which the balloon deflates. One way to speed up deflation can be to shape the distal port 2460 in the form of a funnel outwardly expanding from the inflation lumen 2422. Another way to speed up deflation can be to have two or more inflation lumens 2422 about the circumference of the inner lumen wall 2410 and to have corresponding sets of a stretch-valve tube 2520, a proximal port 2450, and a distal port 2460 for each inflation lumen 2422.

Yet another exemplary embodiment that is not illustrated herein is to combine both of the embodiments of FIGS. 21 to 23 and 24 to 26 to have the fluid 2200 drain out from both of the distal ports 2160, 2460 into both the bladder 2020 and the drain lumen 2112, respectively.

Still another possibility for rapidly deflating an inflated balloon is to drain the fluid 2200 directly into the drain lumen 2712 in a straight line without any longitudinal travel X. This exemplary embodiment is illustrated in FIGS. 27 to 29. FIG. 27 illustrates the balloon portion of the inventive catheter 2700 with the balloon in its uninflated state. An annular inner lumen wall 2710 (red) defines therein a drainage lumen 2712. At one or more circumferential longitudinal extents about the inner lumen wall 2710, an inflation lumen wall 2720 (orange) defines an inflation lumen 2722 and a balloon inflation port 2724 fluidically connected to the inflation lumen 2722; in the inventive catheter, there can be more than one inflation lumen 2722 and corresponding inflation port 2724 even though only one is shown herein. Accordingly, the views of FIGS. 27 to 29 show a cross-section through the single inflation lumen 2722 and single inflation port 2724. A lumen plug 2726 (black) closes the inflation lumen 2722 distal of the inflation port 2724. In this exemplary illustration, the lumen plug 2726 starts at a position distal of the inflation port 2724 at the inflation lumen 2722. This configuration is only exemplary and can start at the inflation port 2724 or anywhere distal thereof.

About the inner lumen and inflation lumen walls 2710, 2720 around the inflation port 2724 is a tube of material that forms the balloon interior wall 2730 (green). The tube of the balloon interior wall 2730 is fluid-tightly sealed against the respective inner walls 2710, 2720 only at the proximal and distal ends of the tube. Accordingly, a pocket is formed therebetween. An outer wall 2740 (yellow) covers all of the walls 2710, 2720, 2726, 2730 in a fluid-tight manner. FIG. 27 illustrates the fluid about to inflate the balloon (indicated with dashed arrows). Because at least the balloon interior wall 2730 and the outer wall 2740 are elastomeric, pressure exerted by the inflating fluid 2200 against these walls will cause them to balloon outwards as, for example, shown in FIG. 28. When the non-illustrated proximal end of the catheter 2700 is sealed with the fluid 2200 therein (e.g., with at least a part of a luer connector as shown in FIG. 3), the catheter 2700 will remain in the shape shown in FIG. 28.

FIG. 28 shows the catheter 2700 correctly inflated in the bladder 2020 and then, if needed, pulled proximally so that the inflated balloon 2810 rests against and substantially seals off the urethra 2030 from the interior of the bladder 2020.

The stretch-valve of the exemplary embodiment of FIGS. 27 to 29 has three different aspects. The first is a hollow, stretch-valve tube 2820 that is disposed in the inflation lumen 2722 to not hinder inflation of the balloon 2810 with the fluid 2200. While the diameter of the stretch-valve tube 2820 can be any size that accommodates unhindered fluid flow through the inflation lumen 2722, one exemplary inner diameter of the stretch-valve tube 2820 is substantially equal to the diameter of the inflation lumen 2722 and the outer diameter of the stretch-valve tube 2820 is just slightly larger than the diameter of the inflation lumen 2722 (e.g., the wall thickness of the tube can be between 0.05 mm and 0.2 mm). The proximal end of the stretch-valve tube 2820 in this exemplary embodiment is proximal of a proximal end of the balloon inner wall 2730. The distal end of the stretch-valve tube 2820 is somewhere near the proximal end of the balloon inner wall 2730; the distal end can be proximal, at, or distal to the proximal end of the balloon inner wall 2730 and selection of this position is dependent upon the amount of stretch S required to actuate

the stretch-valve of the inventive catheter 2700 as described below. In the exemplary embodiment of FIG. 28, the distal end of the stretch-valve tube 2820 is shown between the inflation port 2724 and the proximal end of the balloon inner wall 2730. Two ports are formed, one proximal of the balloon 2810 and one between the inflation port 2724 and the proximal end of the balloon inner wall 2730. A proximal port 2750 is formed through the outer wall 2740 through the inflation lumen wall 2720 to overlap at least a portion of the proximal end of the stretch-valve tube 2820. In this manner, a portion of the outer surface of the proximal end of the stretch-valve tube 2820 at the proximal port 2750 is exposed to the environment but there is no fluid communication between the inflation lumen 2722 and the proximal port 2750. A distal port (white) 2760 is formed through both inflation lumen wall 2720 and the inner wall 2710 distal of the proximal connection of the balloon inner wall 2730 to overlap at least a portion of the distal end of the stretch-valve tube 2820. In this manner, opposing portions of the outer surface of the distal end of the stretch-valve tube 2820 at the distal port 2760 are exposed, one exposed to the interior of the balloon 2810 and one exposed to the drainage lumen 2712 but there is no fluid communication between either the inflation lumen 2722 or the drainage lumen 2712 and the distal port 2760. To secure the stretch-valve tube 2820 in the catheter 2700, the proximal port 2750 is filled with a material that fixes the proximal end of the stretch-valve tube 2820 to at least one of the outer wall 2740 and the inflation lumen wall 2720. In one exemplary embodiment, an adhesive bonds the proximal end of the stretch-valve tube 2820 to both the outer wall 2740 and the inflation lumen wall 2720. In the exemplary embodiment, the adhesive can be the same material as any or all of the walls 2710, 2720, 2730, 2740 or it can be a different material. If the outer wall 2740 is formed by a dipping of the interior parts into a liquid bath of the same material as, for example, a dual lumen extrusion including the inner wall 2710 and the inflation lumen wall 2720, then, when set, the outer wall 2740 will be integral to both the inner wall 2710 and the inflation lumen wall 2720 and will be fixedly connected to the stretch-valve tube 2820 through the proximal port 2750.

In such a configuration, therefore, any proximal movement of the catheter 2700 at or proximal to the proximal port 2750 will also move the stretch-valve tube 2820 proximally; in other words, the distal end of the stretch-valve tube 2820 can slide S within the inflation lumen 2722 in a proximal direction. FIG. 29 illustrates how the slide-valve of the invention operates when the proximal end of the catheter 2700 is pulled to a force that is no greater than just before injury would occur to the urethrovesical junction or the urethra if the catheter 2700 was still inflated when the force was imparted. In an exemplary embodiment of the stretch valve of FIGS. 27 to 29, a pulling force in a range of 1 to 15 pounds will cause the stretch-valve tube 2820 to slide proximally S to place the distal end of the stretch-valve tube 2820 just proximal of the distal port 2760, i.e., the deflation point of the stretch-valve shown in FIG. 29. In another exemplary embodiment, the range of force required to meet the deflation point is between 1 and 5 pounds, in particular, between 1.5 and 2 pounds.

As can be seen in FIG. 29, when the deflation point of the stretch-valve is reached, the interior of the balloon 2810 becomes fluidically connected to both the upper and lower portions of the distal port 2760 in a direct and straight line. Because the distal port 2760 is open to the drainage lumen 2712 (which is open the interior of the bladder 2020 and to the non-illustrated, proximal drain bag) and due to the fact that the bladder is relatively unpressurized as compared to the balloon 2810, an internal pressure is released from the bal-

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loon 2810 to eject the inflating fluid 2200 into the drainage lumen 2712 (depicted by dashed arrows), thereby causing the balloon 2810 to deflate rapidly (depicted by solid opposing arrows). Unlike the embodiments above, the distance X between the deflation port (the upper part of distal port 2760) and the lower part of distal port 2760 is zero—therefore, the rate at which the balloon 2510 deflates cannot be made any faster (other than expanding the area of the distal port 2760). It is further noted that the inflation port 2724 also becomes fluidically connected to the drain lumen 2712 and, therefore, drainage of the fluid 2200 occurs through the inflation port 2724 as well. The cross-sectional area of the inflation lumen 2722, therefore, only slightly impacts the rate of balloon deflation, if at all. One way to speed up deflation can be to shape the distal port 2760 in the form of a funnel outwardly expanding in a direction from the outer circumference of the catheter 2700 inwards towards the drainage lumen 2712. Another way to speed up deflation can be to have two or more inflation lumens 2722 about the circumference of the inner lumen wall 2710 and to have corresponding sets of a stretch-valve tube 2820, a proximal port 2750, and a distal port 2760 for each inflation lumen 2722.

FIG. 30 reproduces FIG. 27 to assist in explaining FIGS. 31 and 32 on the same page. FIGS. 31 and 32 show, respectively, the closed and opened positions of the stretch-valve tube 2820 in FIGS. 28 and 29. These figures are viewed in an orientation turned ninety degrees counterclockwise with regard to a central, longitudinal axis of the catheter 2700 viewed along the axis towards the distal end from the proximal end so that the view looks down upon the distal port 2760. As can be seen, without pulling on the proximal end of the catheter 2700 (FIG. 31), the stretch-valve tube 2820 blocks the distal port 2760. With a proximal force on the proximal end of the catheter 2700, as shown in FIG. 32, the stretch-valve tube 2820 slides and no longer blocks the distal port 2760.

FIGS. 33 to 36 show alternative exemplary embodiments for the automatically deflating, stretch-valve, safety balloon catheter according to the invention. Where various parts of the embodiments are not described with regard to these figures (e.g., the balloon interior wall), the above-mentioned parts are incorporated by reference herein into these embodiments and are not repeated for reasons of brevity.

FIG. 33 illustrates the balloon portion of the inventive catheter 3300 with the balloon 3302 in a partially inflated state. An annular inner lumen wall 3310 defines therein a drainage lumen 3312. At one or more circumferential longitudinal extents about the inner lumen wall 3310, an inflation lumen wall 3320 defines an inflation lumen 3322 and a balloon inflation port 3324 fluidically connected to the inflation lumen 3322; in the inventive catheter, there can be more than one inflation lumen 3322 and corresponding inflation port 3324 even though only one is shown herein. Accordingly, the views of FIGS. 33 to 36 show a cross-section through the single inflation lumen and single inflation port. No lumen plug closes the inflation lumen 3322 distal of the inflation port 3324 as set forth above in alternative embodiments. In this exemplary embodiment, a stretch-valve mechanism 3330 serves to plug the inflation lumen 3322 distal of the inflation port 3324 as described in further detail below. An outer wall 3340 covers all of the interior walls 3310 and 3320 in a fluid-tight manner and forms the exterior of the balloon 3342 but does not cover the distal end of the inflation lumen 3322. The outer wall 3340 is formed in any way described herein and is not discussed in further detail here.

The stretch-valve mechanism 3330 is disposed in the inflation lumen 3322 to not hinder inflation of the balloon 3302 with inflating fluid. A proximal, hollow anchor portion 3332

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is disposed in the inflation lumen 3320 proximal of the inflation port 3324. While the diameter of the hollow anchor portion 3332 can be any size that accommodates unhindered fluid flow through the inflation lumen 3322, one exemplary inner diameter of the hollow anchor portion 3332 is substantially equal to the diameter of the inflation lumen 3322 and the outer diameter of the hollow anchor portion 3332 is just slightly larger than the diameter of the inflation lumen 3322 (e.g., the wall thickness of the tube can be between 0.05 mm and 0.2 mm). The longitudinal length of the hollow anchor portion 3332 is as long as desired to be longitudinally fixedly secured within the inflation lumen 3322 when installed in place. The tube, from its shape alone, can provide the securing connection but, also, an adhesive can be used in any manner, one of which includes creating a proximal port as shown in the above embodiments and utilizing the dipped exterior to form the fixed connection. The distal end of the hollow anchor portion 3332 in this exemplary embodiment is proximal of a proximal end of the balloon 3302. The distal end of the hollow anchor portion 3332 can be nearer to the inflation port 3324, but not at or distal of the inflation port 3324; both ends of the hollow anchor portion 3332 can be proximal, at, or distal to the proximal end of the balloon 3302 and selection of this position is dependent upon the amount of stretch that is desired to actuate the stretch-valve of the inventive catheter 3300 as described below. In the exemplary embodiment of FIG. 33, the stretch-valve mechanism 3330 also includes an intermediate stopper wire 3334 connected at its proximal end to the hollow anchor portion 3332 and a stopper 3336 connected to the distal end of the stopper wire 3334. The stopper 3336 is sized to be slidably disposed in the inflation lumen 3322 while, at the same time, to provide a fluid-tight seal so that liquid cannot pass from one side of the stopper 3336 to the other side within the inflation lumen 3322. The stopper 3336 is located distal of the inflation port 3324. The stopper wire 3334, therefore, spans the inflation port 3324. Because the stopper 3336 must traverse the inflation port 3324, it must be just distal of the inflation port 3324 but the hollow anchor portion can be located anywhere proximal of the inflation port 3324. While the length of the stopper wire 3334 needs to be sufficient to span the inflation port 3324, it can be as long as desired, which will depend on where the hollow anchor portion 3332 resides as well as the amount of stretch desired. As the catheter 3300 stretches more at its proximal end and less at its distal end when pulled from the proximal end, the hollow anchor portion 3332 can be further proximal in the inflation lumen 3322 than shown, and can even be very close to or at the proximal end of the inflation lumen 3322.

In such a configuration, therefore, any proximal movement of the catheter 3300 at or proximal to the inflation port 3324 will also move the stretch-valve mechanism 3330 proximally; in other words, the stopper 3336 slides proximally within the inflation lumen 3322 from distal of the inflation port 3324 to a proximal side of the inflation port 3324. When the proximal end of the catheter 3300 is pulled to move the stopper 3336 across the inflation port 3324 with a force that is no greater than just before injury would occur to the urethrovaginal junction or the urethra if the catheter 3300 was still inflated when the force was imparted, fluid in the balloon 3342 can exit distally out the inflation lumen 3322. In an exemplary embodiment of the stretch valve of FIG. 33, a pulling force in a range of 1 to 15 pounds will cause the stretch-valve mechanism 3330 to slide proximally to place the stopper 3336 just proximal of the inflation port 3324, i.e., the deflation point of the stretch-valve shown in FIG. 33. In another exemplary embodiment, the range of force required to meet the deflation point is between 1 and 5 pounds, in particular, between 1.5

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and 2 pounds. When the stopper 3336 traverses the inflation port 3324, the balloon 3342 automatically deflates and the inflating fluid exits into the bladder out the distal end of the inflation lumen 3332, which is open at the distal end of the catheter 3300.

FIG. 34 illustrates the balloon portion of the inventive catheter 3400 with the balloon 3402 in a partially inflated state. An annular inner lumen wall 3410 defines therein a drainage lumen 3412. At one or more circumferential longitudinal extents about the inner lumen wall 3410, an inflation lumen wall 3420 defines an inflation lumen 3422 and a balloon inflation port 3424 fluidically connected to the inflation lumen 3422; in the inventive catheter, there can be more than one inflation lumen 3422 and corresponding inflation port 3424 even though only one is shown herein. No lumen plug closes the inflation lumen 3422 distal of the inflation port 3424 as set forth above in alternative embodiments. In this exemplary embodiment, a stretch-valve mechanism 3430 serves to plug the inflation lumen 3422 distal of the inflation port 3424 as described in further detail below. An outer wall 3440 covers all of the interior walls 3410 and 3420 in a fluid-tight manner and forms the exterior of the balloon 3442 but does not cover the distal end of the inflation lumen 3422. The outer wall 3440 is formed in any way described herein and is not discussed in further detail here.

The stretch-valve mechanism 3430 is disposed in the inflation lumen 3422 and does not hinder inflation of the balloon 3402 with inflating fluid. A proximal, hollow anchor portion 3432 is disposed in the inflation lumen 3420 proximal of the inflation port 3424. While the diameter of the hollow anchor portion 3432 can be any size that accommodates unhindered fluid flow through the inflation lumen 3422, one exemplary inner diameter of the hollow anchor portion 3432 is substantially equal to the diameter of the inflation lumen 3422 and the outer diameter of the hollow anchor portion 3432 is just slightly larger than the diameter of the inflation lumen 3422 (e.g., the wall thickness of the tube can be between 0.05 mm and 0.2 mm). The longitudinal length of the hollow anchor portion 3432 is as long as desired to be longitudinally fixedly secured within the inflation lumen 3422 when installed in place. The tube, from its shape alone, can provide the securing connection but, also, an adhesive can be used in any manner, one of which includes creating a proximal port as shown in the above embodiments and utilizing the dipped exterior to form the fixed connection. The distal end of the hollow anchor portion 3432 in this exemplary embodiment is at a proximal side of the balloon 3402. The distal end of the hollow anchor portion 3432 can be nearer to the inflation port 3424, but not at or distal of the inflation port 3424; both ends of the hollow anchor portion 3432 can be proximal, at, or distal to the proximal end of the balloon 3402 and selection of this position is dependent upon the amount of stretch that is desired to actuate the stretch-valve of the inventive catheter 3400 as described below. In the exemplary embodiment of FIG. 34, the stretch-valve mechanism 3430 also includes an intermediate hollow stopper tube 3434 connected at its proximal end to the hollow anchor portion 3432 and a stopper 3436 connected to the distal end of the stopper tube 3434. The stopper tube 3434 is only a circumferential portion of the hollow anchor portion 3432 and is located opposite the inflation port 3424 so that it does not obstruct fluid flow through the inflation port 3424. The stopper, in contrast, is a solid cylinder having the same outer diameter as the hollow anchor portion 3432. The entire mechanism 3430 is sized to be slidably disposed in the inflation lumen 3422 while, at the same time, to provide a fluid-tight seal at the stopper 3436 so that liquid cannot pass from one side of the stopper 3436 to the other side

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within the inflation lumen 3422. The stopper 3436 is located distal of the inflation port 3424. The stopper tube 3434, therefore, spans the inflation port 3424. Because the stopper 3436 must traverse the inflation port 3424, it must be just distal of the inflation port 3424 but the hollow anchor portion 3432 can be located anywhere proximal of the inflation port 3424. While the length of the stopper tube 3434 needs to be sufficient to span the inflation port 3424, it can be as long as desired, which will depend on where the hollow anchor portion 3432 resides. As the catheter 3400 stretches more at its proximal end and less at its distal end when pulled from the proximal end, the hollow anchor portion 3422 can be further proximal in the inflation lumen 3422 than shown, and can even be very close to or at the proximal end of the inflation lumen 3422.

In such a configuration, therefore, any proximal movement of the catheter 3400 at or proximal to the inflation port 3424 will also move the stretch-valve mechanism 3430 proximally; in other words, the stopper 3436 slides proximally within the inflation lumen 3422 from distal of the inflation port 3424 to a proximal side of the inflation port 3424. When the proximal end of the catheter 3400 is pulled to move the stopper 3436 across the inflation port 3424 with a force that is no greater than just before injury would occur to the urethrovaginal junction or the urethra if the catheter 3400 was still inflated when the force was imparted, fluid in the balloon 3442 can exit distally out the inflation lumen 3422. In an exemplary embodiment of the stretch valve of FIG. 34, a pulling force in a range of 1 to 15 pounds will cause the stretch-valve mechanism 3430 to slide proximally to place the stopper 3436 just proximal of the inflation port 3424, i.e., the deflation point of the stretch-valve shown in FIG. 34. In another exemplary embodiment, the range of force required to meet the deflation point is between 1 and 5 pounds, in particular, between 1.5 and 2 pounds. When the stopper 3436 traverses the inflation port 3424, the balloon 3442 automatically deflates and the inflating fluid exits into the bladder out the distal end of the inflation lumen 3432, which is open at the distal end of the catheter 3400.

FIG. 35 illustrates the balloon portion of the inventive catheter 3500 with the balloon 3502 in a partially inflated state. An annular inner lumen wall 3510 defines therein a drainage lumen 3512. At one or more circumferential longitudinal extents about the inner lumen wall 3510, an inflation lumen wall 3520 defines an inflation lumen 3522 and a balloon inflation port 3524 fluidically connected to the inflation lumen 3522; in the inventive catheter, there can be more than one inflation lumen 3522 and corresponding inflation port 3524 even though only one is shown herein. No lumen plug closes the inflation lumen 3522 distal of the inflation port 3524 as set forth above in alternative embodiments. In this exemplary embodiment, a stretch-valve mechanism 3530 serves to plug the inflation lumen 3522 distal of the inflation port 3524 as described in further detail below. An outer wall 3540 covers all of the interior walls 3510 and 3520 in a fluid-tight manner and forms the exterior of the balloon 3542 but does not cover the distal end of the inflation lumen 3522. The outer wall 3540 is formed in any way described herein and is not discussed in further detail here.

The stretch-valve mechanism 3530 is disposed in the inflation lumen 3522 to not hinder inflation of the balloon 3502 with inflating fluid. A proximal, hollow anchor portion 3532 is disposed in the inflation lumen 3520 proximal of the inflation port 3524. While the diameter of the hollow anchor portion 3532 can be any size that accommodates unhindered fluid flow through the inflation lumen 3522, one exemplary inner diameter of the hollow anchor portion 3532 is substan-

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tially equal to the diameter of the inflation lumen 3522 and the outer diameter of the hollow anchor portion 3532 is just slightly larger than the diameter of the inflation lumen 3522 (e.g., the wall thickness of the tube can be between 0.05 mm and 0.2 mm). The longitudinal length of the hollow anchor portion 3532 is as long as desired to be longitudinally fixedly secured within the inflation lumen 3522 when installed in place. The tube, from its shape alone, can provide the securing connection but, also, an adhesive can be used in any manner, one of which includes creating a proximal port as shown in the above embodiments and utilizing the dipped exterior to form the fixed connection. The distal end of the hollow anchor portion 3532 in this exemplary embodiment is at a proximal side of the balloon 3502. The distal end of the stretch-valve mechanism 3530 can be nearer to the inflation port 3524, but not at or distal of the inflation port 3524; both ends of the hollow anchor portion 3532 can be proximal, at, or distal to the proximal end of the balloon 3502 and selection of this position is dependent upon the amount of stretch that is desired to actuate the stretch-valve of the inventive catheter 3500 as described below. In the exemplary embodiment of FIG. 35, the stretch-valve mechanism 3530 also includes an intermediate bias device 3534, such as a spring, connected at its proximal end to the hollow anchor portion 3532 and a stopper 3536 connected to the distal end of the bias device 3534. The bias device 3534 is located at the inflation port 3524 but not to obstruct fluid flow through the inflation port 3524. The stopper 3536, in contrast, is a solid cylinder having the same outer diameter as the hollow anchor portion 3532. The entire mechanism 3530 is sized to be slidably disposed in the inflation lumen 3522 while, at the same time, to provide a fluid-tight seal at the stopper 3536 so that liquid cannot pass from one side of the stopper 3536 to the other side within the inflation lumen 3522. The stopper 3536 is located distal of the inflation port 3524. To prevent distal movement of the stopper 3536, a restrictor 3538 is provided distal of the stopper 3536. The bias device 3534, therefore, spans the inflation port 3524. Because the stopper 3536 must traverse the inflation port 3524, it must be just distal of the inflation port 3524 but the hollow anchor portion 3532 can be located anywhere proximal of the inflation port 3524. While the length of the bias device 3534 needs to be sufficient to span the inflation port 3524, it can be as long as desired, which will depend on where the hollow anchor portion 3532 resides. As the catheter 3500 stretches more at its proximal end and less at its distal end when pulled from the proximal end, the hollow anchor portion 3522 can be further proximal in the inflation lumen 3522 than shown, and can even be very close to or at the proximal end of the inflation lumen 3522.

In such a configuration, therefore, any proximal movement of the catheter 3500 at or proximal to the inflation port 3524 will also move the stretch-valve mechanism 3530 proximally; in other words, the stopper 3536 slides proximally within the inflation lumen 3522 from distal of the inflation port 3524 to a proximal side of the inflation port 3524. When the proximal end of the catheter 3500 is pulled to move the stopper 3536 across the inflation port 3524 with a force that is no greater than just before injury would occur to the urethrovaginal junction or the urethra if the catheter 3500 was still inflated when the force was imparted, fluid in the balloon 3542 can exit distally out the inflation lumen 3522. In an exemplary embodiment of the stretch valve of FIG. 35, a pulling force in a range of 1 to 15 pounds will cause the stretch-valve mechanism 3530 to slide proximally to place the stopper 3536 just proximal of the inflation port 3524, i.e., the deflation point of the stretch-valve shown in FIG. 35. In another exemplary embodiment, the range of force required to meet the deflation

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point is between 1 and 5 pounds, in particular, between 1.5 and 2 pounds. When the stopper 3536 traverses the inflation port 3524, the balloon 3542 automatically deflates and the inflating fluid exits into the bladder out the distal end of the inflation lumen 3532, which is open at the distal end of the catheter 3500.

FIG. 36 illustrates the balloon portion of the inventive catheter 3600 with the balloon 3602 in a partially inflated state. An annular inner lumen wall 3610 defines therein a drainage lumen 3612. At one or more circumferential longitudinal extents about the inner lumen wall 3610, an inflation lumen wall 3620 defines an inflation lumen 3622 and a balloon inflation port 3624 fluidically connected to the inflation lumen 3622; in the inventive catheter, there can be more than one inflation lumen 3622 and corresponding inflation port 3624 even though only one is shown herein. No lumen plug closes the inflation lumen 3622 distal of the inflation port 3624 as set forth above in alternative embodiments. In this exemplary embodiment, a stretch-valve mechanism 3630 serves to plug the inflation lumen 3622 distal of the inflation port 3624 as described in further detail below. An outer wall 3640 covers all of the interior walls 3610 and 3620 in a fluid-tight manner and forms the exterior of the balloon 3642 but does not cover the distal end of the inflation lumen 3622. The outer wall 3640 is formed in any way described herein and is not discussed in further detail here.

The stretch-valve mechanism 3630 is disposed in the inflation lumen 3622 to not hinder inflation of the balloon 3602 with inflating fluid. A non-illustrated proximal anchor is disposed in the inflation lumen 3620 proximal of the inflation port 3624. The proximal anchor can be any size or shape that accommodates unhindered fluid flow through the inflation lumen 3622, one exemplary inner diameter of the hollow anchor portion is a tube substantially equal to the diameter of the inflation lumen 3622 with an outer diameter just slightly larger than the diameter of the inflation lumen 3622 (e.g., the thickness of the tube can be between 0.07 mm and 0.7 mm). The longitudinal length of this hollow anchor can be as long as desired to be longitudinally fixedly secured within the inflation lumen 3622 when installed in place. The anchor in this exemplary embodiment is at or near the non-illustrated proximal end of the inflation lumen 3622. The distal end of the stretch-valve mechanism 3630 can be nearer to the inflation port 3624, but not at or distal of the inflation port 3624; selection of the anchor's position is dependent upon the amount of stretch that is desired to actuate the stretch-valve of the inventive catheter 3600 as described below. In the exemplary embodiment of FIG. 36, the stretch-valve mechanism 3630 also includes an intermediate cord 3634, either inelastic or elastic, connected at its proximal end to the anchor. A stopper 3636 is connected to the distal end of the cord 3634. The cord 3634 is located at the inflation port 3624 but not to obstruct fluid flow through the inflation port 3624. The stopper 3636, in contrast, is a solid cylinder having the a diameter that allows it to slidably move within the inflation lumen 3622 when the cord 3634 pulls it but, at the same time, to provide a fluid-tight seal so that liquid cannot pass from one side of the stopper 3636 to the other side within the inflation lumen 3622. The stopper 3636 is located distal of the inflation port 3624. To prevent distal movement of the stopper 3636, a restrictor 3638 is provided distal of the stopper 3636. The cord 3634, therefore, spans the inflation port 3624. Because the stopper 3636 must traverse the inflation port 3624, it must be just distal of the inflation port 3624 but the anchor can be located anywhere proximal of the inflation port 3624. While the length of the cord 3634 needs to be sufficient to span the inflation port 3624, it can be as long as desired, which will

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depend on where the anchor resides. As the catheter **3600** stretches more at its proximal end and less at its distal end when pulled from the proximal end, the anchor can be further proximal in the inflation lumen **3622** than shown, and can even be very close to or at the proximal end of the inflation lumen **3622**. It can even be attached to the luer connector half that prevents fluid from flowing out the proximal end of the inflation lumen **3622**.

In such a configuration, therefore, any proximal movement of the catheter **3600** at the proximal end where the anchor resides will also move the stretch-valve mechanism **3630** proximally; in other words, the stopper **3636** slides proximally within the inflation lumen **3622** from distal of the inflation port **3624** to a proximal side of the inflation port **3624**. When the proximal end of the catheter **3600** is pulled to move the stopper **3636** across the inflation port **3624** with a force that is no greater than just before injury would occur to the urethrovessical junction or the urethra if the catheter **3600** was still inflated when the force was imparted, fluid in the balloon **3642** can exit distally out the inflation lumen **3622**. In an exemplary embodiment of the stretch valve of FIG. **36**, a pulling force in a range of 1 to 15 pounds will cause the stretch-valve mechanism **3630** to slide proximally to place the stopper **3636** just proximal of the inflation port **3624**, i.e., the deflation point of the stretch-valve shown in FIG. **36**. In another exemplary embodiment, the range of force required to meet the deflation point is between 1 and 5 pounds, in particular, between 1.5 and 2 pounds. When the stopper **3636** traverses the inflation port **3624**, the balloon **3642** automatically deflates and the inflating fluid exits into the bladder out the distal end of the inflation lumen **3622**, which is open at the distal end of the catheter **3600**.

An alternative exemplary embodiment combines the embodiments of FIGS. **30** and **36** to tether the tube **2820** at the proximal end of the catheter.

FIG. **37** illustrates the balloon portion of the inventive catheter **3700** with the balloon **3742** in a partially inflated state. An annular inner lumen wall **3710** defines therein a drainage lumen **3712**. At one or more circumferential longitudinal extents about the inner lumen wall **3710**, an inflation lumen wall **3720** defines an inflation lumen **3722** and a balloon inflation port **3724** fluidically connected to the inflation lumen **3722**; in the inventive catheter, there can be more than one inflation lumen **3722** and corresponding inflation port **3724** even though only one is shown herein. A lumen plug **3736** fluidically closes the inflation lumen **3722** distal of the inflation port **3724** so that all inflation fluid **3702** is directed into the balloon **3742**. The lumen plug **3736** can plug any point or extent from the inflation port **3724** distally. An outer wall **3740** covers all of the interior walls **3710** and **3720** in a fluid-tight manner and forms the exterior of the balloon **3742** but does not cover the distal end of the drainage lumen **3712**. The outer wall **3740** is formed in any way described herein and is not discussed in further detail here.

In this exemplary embodiment, a hollow, stretch-valve tube **3730** is disposed in the drainage lumen **3712** to not hinder drainage of the fluid to be drained (e.g., urine). While the diameter of the stretch-valve tube **3730** can be any size that accommodates unhindered fluid flow through the drainage lumen **3712**, one exemplary inner diameter of the stretch-valve tube **3730** is substantially equal to the diameter of the drainage lumen **3712** and the outer diameter of the stretch-valve tube **3730** is just slightly larger than the diameter of the drainage lumen **3712** (e.g., the wall thickness of the tube can be between 0.07 mm and 0.7 mm). The proximal end of the stretch-valve tube **3730** in this exemplary embodiment is proximal of a proximal end of a deflation port **3760**. The distal

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end of the stretch-valve tube **3730** is not distal of the distal end of the balloon **3742** so that the balloon **3742** can be deflated; the distal end can be anywhere between the two ends of the balloon **3742** but is shown in an intermediate position in FIG. **37**. The distal end of the stretch-valve tube **3730** is at a distance **S** distal of the deflation port **3760** and selection of this distance **S** is dependent upon the amount of stretch required to actuate the stretch-valve of the inventive catheter **3700** as described below. In the exemplary embodiment of FIG. **37**, the longitudinal length of the deflation port **3760** is shown as less than one half of the longitudinal length of the stretch-valve tube **3730**. The drainage port **3760** is formed through the inner lumen wall **3710** and the stretch-valve tube **3730** is positioned to overlap at least the drainage port **3760**. In this manner, a portion of the outer surface of the distal end of the stretch-valve tube **3730** closes off the drainage port **3760** to prevent fluid communication between the balloon **3742** and the drainage lumen **3712** through the drainage port **3760**.

To secure the stretch-valve tube **3730** in the catheter **3700**, a proximal anchor **3732** is disposed in the drainage lumen **3710** away from the deflation port **3760**, here proximally. The proximal anchor **3732** can be any size or shape that accommodates unhindered fluid flow through the drainage lumen **3712**, one exemplary inner diameter of the hollow anchor **3732** being a tube or ring substantially equal to the diameter of the drainage lumen **3712** with an outer diameter just slightly larger than the diameter of the drainage lumen **3712** (e.g., the thickness of the tube can be between 0.07 mm and 0.7 mm). The longitudinal length of this hollow anchor **3732** can be as long as desired but just enough to longitudinally fixedly secure the stretch-valve tube **3730** within the drainage lumen **3712** when installed in place. The anchor **3732** in this exemplary embodiment is at the proximal end of the balloon **3742** but can be further inside the balloon **3742** (distal) or entirely proximal of the balloon **3742**. In an exemplary embodiment, the anchor **3732** has a stepped distal orifice that permits the proximal end of the stretch-valve tube **3730** to be, for example, press-fit therein for permanent connection. In another exemplary embodiment, the anchor **3732** is an adhesive or glue that fixes the proximal end of the stretch-valve tube **3730** longitudinally in place within the drainage lumen **3712**. The adhesive can be the same material as any or all of the walls **3710**, **3720**, **3740** or it can be a different material. In an exemplary non-illustrated embodiment where a fixation port or set of fixation ports are formed through the inner wall **3710** proximal of the proximal-most end of the balloon **3742** and about the proximal end of the stretch-valve tube **3730**, if the outer wall **3740** is formed by a dipping of the interior parts into a liquid bath of the same material as, for example, a dual lumen extrusion including the inner wall **3710** and the inflation lumen wall **3720**, then, when set, the outer wall **3740** will be integral to both the inner wall **3710** and the inflation lumen wall **3720** and will be fixedly connected to the stretch-valve tube **3730** through the fixation port(s).

In such a configuration, therefore, any proximal movement of the catheter **3700** at or proximal to the drainage port **3760** will also move the stretch-valve tube **3730** proximally; in other words, the distal end of the stretch-valve tube **3730** can slide within the drainage lumen **3712** in a proximal direction. When the proximal end of the catheter **3700** is pulled to a force that is no greater than just before injury would occur to the urethrovessical junction or the urethra if the catheter **3700** was still inflated when the force was imparted, the force will cause the stretch-valve tube **3730** to slide proximally to place the distal end of the stretch-valve tube **3730** just proximal of the drainage port **3760**, e.g., with a pulling force in a range of



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1 to 15 pounds. In another exemplary embodiment, the range of force required to meet the deflation point is between 1 and 5 pounds, in particular, between 1.5 and 2 pounds.

When the deflation point of the stretch-valve tube **3730** starts, the interior of the balloon **3742** becomes fluidically connected directly into the drainage lumen **3712** (which is open to the interior of the bladder **2020** and to the non-illustrated, proximal drain bag) and, due to the fact that the bladder is relatively unpressurized as compared to the balloon **3742**, all internal pressure is released from the balloon **3742** to eject the inflating fluid **3702** directly into the drainage lumen **3712**, thereby causing the balloon **3742** to deflate rapidly. Because there is no intermediate structure between the balloon inflating fluid **3702** and the drainage lumen **3712**, the rate at which the balloon **3742** deflates is fast. One way to speed up deflation can be to shape the drainage port **3760** in the form of a funnel outwardly expanding in a direction from the outer wall **3740** towards the interior of the catheter **3700**. Another way to speed up deflation can be to have two or more drainage ports **3760** about the circumference of the inner lumen wall **3710** and/or to enlarge the cross-sectional area of the drainage port **3760**.

FIG. **38** illustrates a balloon portion of the inventive catheter **3800** with a balloon **3842** in a partially inflated state. An annular inner lumen wall **3810** defines therein a drainage lumen **3812**. At one or more circumferential longitudinal extents about the inner lumen wall **3810**, an inflation lumen wall **3820** defines an inflation lumen **3822** and a balloon inflation port **3824** fluidically connected to the inflation lumen **3822**; in the inventive catheter, there can be more than one inflation lumen **3822** and corresponding inflation port **3824** even though only one is shown herein. A lumen plug **3836** fluidically closes the inflation lumen **3822** distal of the inflation port **3824** so that all inflation fluid **3802** is directed into the balloon **3842**. The lumen plug **3736** can plug any point or extent from the inflation port **3724** distally. An outer wall **3840** covers all of the interior walls **3810** and **3820** in a fluid-tight manner and forms the exterior of the balloon **3842** but does not cover the distal end of the drainage lumen **3812**. The outer wall **3840** is formed in any way described herein and is not discussed in further detail here.

In this exemplary embodiment, a hollow, stretch-valve tube **3830** is disposed in the drainage lumen **3812** to not hinder drainage of the fluid to be drained (e.g., urine). While the diameter of the stretch-valve tube **3830** can be any size that accommodates unhindered fluid flow through the drainage lumen **3812**, one exemplary inner diameter of the stretch-valve tube **3830** is substantially equal to the diameter of the drainage lumen **3812** and the outer diameter of the stretch-valve tube **3830** is just slightly larger than the diameter of the drainage lumen **3812** (e.g., the wall thickness of the tube can be between 0.07 mm and 0.7 mm). The proximal end of the stretch-valve tube **3830** in this exemplary embodiment is proximal of a proximal end of a deflation port **3860**. The distal end of the stretch-valve tube **3830** is not distal of the distal end of the balloon **3842** so that the balloon **3842** can be deflated; the distal end can be anywhere between the two ends of the balloon **3842** but is shown in an intermediate position in FIG. **38**. The distal end of the stretch-valve tube **3830** is at a distance **S** distal of the deflation port **3860** and selection of this distance **S** is dependent upon the amount of stretch required to actuate the stretch-valve of the inventive catheter **3800** as described below. In the exemplary embodiment of FIG. **38**, the longitudinal length of the deflation port **3760** is shown as less than one half of the longitudinal length of the stretch-valve tube **3830**. The drainage port **3860** is formed through the inner lumen wall **3810** and the stretch-valve tube

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**3830** is positioned to overlap at least the drainage port **3860**. In this manner, a portion of the outer surface of the distal end of the stretch-valve tube **3830** closes off the drainage port **3860** to prevent fluid communication between the balloon **3842** and the drainage lumen **3812** through the drainage port **3860**.

In this exemplary embodiment, in comparison to the embodiment of FIG. **37**, a second drainage port **3862** is provided in the inner lumen wall **3810** aligned with the drainage port **3860**, and both drainage ports **3860**, **3862** are aligned with the inflation port **3824**. As such, when the stretch-valve tube **3830** moves proximally to uncover the drainage ports **3860**, **3862**, inflation fluid **3802** from inside the balloon **3842** exits from both the inflation port **3824** and the drainage port **3860**.

To secure the stretch-valve tube **3830** in the catheter **3800**, a proximal anchor **3832** is disposed in the drainage lumen **3810** away from the deflation ports **3860**, **3862**, here proximally. The proximal anchor **3832** can be any size or shape that accommodates unhindered fluid flow through the drainage lumen **3812**, one exemplary inner diameter of the hollow anchor **3832** being a tube or ring substantially equal to the diameter of the drainage lumen **3812** with an outer diameter just slightly larger than the diameter of the drainage lumen **3812** (e.g., the thickness of the tube can be between 0.07 mm and 0.7 mm). The longitudinal length of this hollow anchor **3832** can be as long as desired but just enough to longitudinally fixedly secure the stretch-valve tube **3830** within the drainage lumen **3812** when installed in place. The anchor **3832** in this exemplary embodiment is at the proximal end of the balloon **3842** but can be further inside the balloon **3842** (distal) or entirely proximal of the balloon **3842**. In an exemplary embodiment, the anchor **3832** has a stepped distal orifice that permits the proximal end of the stretch-valve tube **3830** to be, for example, press-fit therein for permanent connection. In another exemplary embodiment, the anchor **3832** is an adhesive or glue that fixes the proximal end of the stretch-valve tube **3830** longitudinally in place within the drainage lumen **3812**. The adhesive can be the same material as any or all of the walls **3810**, **3820**, **3840** or it can be a different material. In an exemplary non-illustrated embodiment where a fixation port or set of fixation ports are formed through the inner wall **3810** proximal of the proximal-most end of the balloon **3842** and about the proximal end of the stretch-valve tube **3830**, if the outer wall **3840** is formed by a dipping of the interior parts into a liquid bath of the same material as, for example, a dual lumen extrusion including the inner wall **3810** and the inflation lumen wall **3820**, then, when set, the outer wall **3840** will be integral to both the inner wall **3810** and the inflation lumen wall **3820** and will be fixedly connected to the stretch-valve tube **3820** through the fixation port(s).

In such a configuration, therefore, any proximal movement of the catheter **3800** at or proximal to the drainage ports **3860**, **3862** will also move the stretch-valve tube **3830** proximally; in other words, the distal end of the stretch-valve tube **3830** can slide within the drainage lumen **3812** in a proximal direction. When the proximal end of the catheter **3800** is pulled to a force that is no greater than just before injury would occur to the urethrovaginal junction or the urethra if the catheter **3800** was still inflated when the force was imparted, the force will cause the stretch-valve tube **3830** to slide proximally to place the distal end of the stretch-valve tube **3830** just proximal of the drainage ports **3860**, **3862**, e.g., with a pulling force in a range of 1 to 15 pounds. In another exemplary embodi-



ment, the range of force required to meet the deflation point is between 1 and 5 pounds, in particular, between 1.5 and 2 pounds.

When the deflation point of the stretch-valve tube **3830** starts, the interior of the balloon **3842** becomes fluidically connected directly into the drainage lumen **3812** (which is open to the interior of the bladder **2020** and to the non-illustrated, proximal drain bag) and, due to the fact that the bladder is relatively unpressurized as compared to the balloon **3842**, all internal pressure is released from the balloon **3842** to eject the inflating fluid **3802** directly into the drainage lumen **3812**, thereby causing the balloon **3842** to deflate rapidly. Because there is no intermediate structure between the balloon inflating fluid **3802** and the drainage lumen **3812**, the rate at which the balloon **3842** deflates is fast. One way to speed up deflation can be to shape the drainage ports **3860**, **3862** in the form of a funnel outwardly expanding in a direction from the outer wall **3840** towards the interior of the catheter **3800**. Another way to speed up deflation can be to have two or more drainage ports **3860** about the circumference of the inner lumen wall **3810** and/or to enlarge the cross-sectional area of the drainage ports **3860**, **3862**.

Reference is made to the flow chart of FIG. **39** to explain one exemplary embodiment of a process for making a catheter according to the embodiment of FIGS. **21** to **23**.

The catheter starts, in Step **3910** with a dual lumen extrusion of latex. This extrusion, therefore, defines the annular inner lumen wall **2110** with the drainage lumen **2112** and, at one or more circumferential longitudinal extents about the inner lumen wall **2110**, an inflation lumen wall **2120** with the inflation lumen **2122**. The dual lumen, therefore, already includes both the drainage lumen **2112** and the inflation lumen **2122**. Both lumen **2112**, **2122**, however, are extruded without obstruction and without radial ports. Therefore, in order to have the inflation port **2124**, a radial hole needs to be created between the outside surface of the extrusion and the inflation lumen.

In step **3912**, the balloon inflation port **2124** is made to fluidically connect the environment of the extrusion to the inflation lumen **2122**.

Sealing off of the distal end of the inflation lumen **2122** can be performed in Step **3914** by inserting or creating a plug **2126** therein or the sealing can occur simultaneously with the creation of the outer wall **2140** below.

In step **3916**, a balloon sleeve **2130** is placed about the inflation port **2124** and is fixed to the exterior of the inflation lumen wall **2120** at both ends to define a fluid-tight balloon interior **2200** therebetween. As such, inflation of the balloon **2210** can occur through the inflation lumen **2122**. For example, the tube **2130** making up the inner balloon wall is slid over the distal end of the dual-lumen extrusion to cover the inflation port **2124** and is fluid-tightly sealed to the inner multi-lumen extrusion at both ends of the tube but not in the intermediate portion. This tube can be made of latex as well and, therefore, can be secured to the latex multi-lumen extrusion in any known way to bond latex in a fluid-tight manner.

In step **3918**, the entire sub-assembly is covered with the outer wall **2140**. For example, the entire sub-assembly is dipped into latex in its liquid form to create the outer wall **2140**. In the alternative embodiment where a distal inflation lumen plug is not used, the latex can be allowed to enter at least a portion of the distal end of the inflation lumen **2122** but not so far as to block the inflation port **2124**. When the latex cures, the balloon **2210** is fluid tight and can only be fluidically connected to the environment through the proximal-most opening of the inflation port, which is fluidically connected to the inflation lumen **2122**. In this process, the inner

wall **2110**, the inflation lumen wall **2120**, the plug **2126**, the balloon wall **2130**, and the outer wall **2140** are all made of the same latex material and, therefore, together, form a very securely water-tight balloon **2210**.

The sub-process described in Steps **3910** to **3920** can be skipped if desired and, instead, completed by utilizing a standard Foley catheter, on which the following steps are performed.

The stretch valve is now created. A proximal port **2150** is formed through the outer wall **2140** and through the inflation lumen wall **2020** in step **3920**. A distal port **2160** is formed through the outer wall **2140** and through the inflation lumen wall **2020** in step **3922**. Then, in step **3924**, the stretch-valve tube **2220** is inserted through either one of the proximal or distal ports **2150**, **2160** such that the proximal port **2150** overlaps at least a portion of the proximal end of the stretch-valve tube **2220** and the distal port **2160** overlaps at least a portion of the distal end of the stretch-valve tube **2220**. In this manner, two portions of the outer surface of the proximal end of the stretch-valve tube **2220** at the proximal and distal ports **2150**, **2160** are exposed to the environment but there is no fluid communication with the inflation lumen **2122** and the proximal or distal ports **2150**, **2160**.

In Step **3926**, the proximal port **2150** is used to secure the stretch-valve tube **2220** in the catheter **2100**. In one exemplary embodiment, the proximal port **2150** is filled with a material that fixes the proximal end of the stretch-valve tube **2220** to at least one of the outer wall **2140** and the inflation lumen wall **2020**. In an exemplary embodiment, an adhesive bonds the proximal end of the stretch-valve tube **2220** to both the outer wall **2140** and the inflation lumen wall **2120**. In another exemplary embodiment, a portion of the present sub-assembly is dipped into latex in its liquid form to plug the proximal port **2150** and fixedly secure the stretch-valve tube **2220** to both the outer wall **2140** and the inflation lumen wall **2120**. When the latex cures, the connection at the proximal port **2150** is fluid tight and no longer permits fluidic connection to the environment therethrough. In this process, therefore, the filled proximal port **2150**, the inflation lumen wall **2120**, and the outer wall **2140** are all made of the same latex material and, therefore, together, form a very securely water-tight connection.

In such a configuration, therefore, any proximal movement of the catheter **2100** at or proximal of the proximal port **2150** will also move the stretch-valve tube **2220** proximally; in other words, the distal end of the stretch-valve tube **2220** can slide within the inflation lumen **2122** in a proximal direction.

Reference is also made to the flow chart of FIG. **39** to explain one exemplary embodiment of a process for making a catheter according to the embodiment of FIGS. **24** to **26**.

The catheter starts, in Step **3910** with a dual lumen extrusion of latex. This extrusion, therefore, defines the annular inner lumen wall **2410** with the drainage lumen **2412** and, at one or more circumferential longitudinal extents about the inner lumen wall **2410**, an inflation lumen wall **2420** with the inflation lumen **2422**. The dual lumen, therefore, already includes both the drainage lumen **2412** and the inflation lumen **2422**. Both lumens **2412**, **2422**, however, are extruded without obstruction and without radial ports. Therefore, in order to have the inflation port **2424**, a radial hole needs to be created between the outside surface of the extrusion and the inflation lumen.

In Step **3912**, the balloon inflation port **2424** is made to fluidically connect the environment of the extrusion to the inflation lumen **2422**.

Sealing off of the distal end of the inflation lumen **2422** can be performed in Step **3914** by inserting or creating a plug

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2426 therein or the sealing can occur simultaneously with the creation of the outer wall 2440 below.

In Step 3916, a balloon sleeve 2430 is placed about the inflation port 2424 and is fixed to the exterior of the inflation lumen wall 2420 at both ends to define a fluid-tight balloon interior 2200 therebetween. As such, inflation of the balloon 2240 can occur through the inflation lumen 2422. For example, the tube 2430 making up the inner balloon wall is slid over the distal end of the dual-lumen extrusion to cover the inflation port 2424 and is fluid-tightly sealed to the inner multi-lumen extrusion at both ends of the tube but not in the intermediate portion. This tube can be made of latex as well and, therefore, can be secured to the latex multi-lumen extrusion in any known way to bond latex in a fluid-tight manner.

In Step 3918, the entire sub-assembly is covered with the outer wall 2440. For example, the entire sub-assembly is dipped into latex in its liquid form to create the outer wall 2440. In the alternative embodiment where a distal inflation lumen plug is not used, the latex can be allowed to enter at least a portion of the distal end of the inflation lumen 2422 but not so far as to block the inflation port 2424. When the latex cures, the balloon 2240 is fluid tight and can only be fluidically connected to the environment through the proximal-most opening of the inflation port, which is fluidically connected to the inflation lumen 2422. In this process, the inner wall 2410, the inflation lumen wall 2420, the plug 2426, the balloon wall 2430, and the outer wall 2440 are all made of the same latex material and, therefore, together, form a very securely water-tight balloon 2240.

The sub-process described in Steps 3910 to 3920 can be skipped if desired and, instead, completed by utilizing a standard Foley catheter, on which the following Steps are performed.

The stretch valve is now created. A proximal port 2450 is formed through the outer wall 2440 and through the inflation lumen wall 2020 in Step 3920. A distal port 2460 is formed through the inner wall 2410 into the inflation lumen 2422 in Step 3922. Then, in Step 3924, the stretch-valve tube 2520 is inserted through either one of the proximal or distal ports 2450, 2460 such that the proximal port 2450 overlaps at least a portion of the proximal end of the stretch-valve tube 2520 and the distal port 2460 overlaps at least a portion of the distal end of the stretch-valve tube 2520. In this manner, one portion of the outer surface of the proximal end of the stretch-valve tube 2520 at the proximal port 2450 is exposed to the drain lumen 2412 and another portion of the outer surface of the distal end of the stretch-valve tube 2520 at the distal port 2460 is exposed to the environment but there is no fluid communication with the inflation lumen 2422 to either of the proximal or distal ports 2450, 2460.

In Step 3926, the proximal port 2450 is used to secure the stretch-valve tube 2520 in the catheter 2400. In one exemplary embodiment, the proximal port 2450 is filled with a material that fixes the proximal end of the stretch-valve tube 2520 to at least one of the outer wall 2440 and the inflation lumen wall 2020. In an exemplary embodiment, an adhesive bonds the proximal end of the stretch-valve tube 2520 to both the outer wall 2440 and the inflation lumen wall 2420. In another exemplary embodiment, a portion of the present sub-assembly is dipped into latex in its liquid form to plug the proximal port 2450 and fixedly secure the stretch-valve tube 2520 to both the outer wall 2440 and the inflation lumen wall 2420. When the latex cures, the connection at the proximal port 2450 is fluid tight and no longer permits fluidic connection to the environment therethrough. In this process, therefore, the filled proximal port 2450, the inflation lumen wall

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2420, and the outer wall 2440 are all made of the same latex material and, therefore, together, form a very securely water-tight connection.

In such a configuration, therefore, any proximal movement of the catheter 2400 at or proximal of the proximal port 2450 will also move the stretch-valve tube 2520 proximally; in other words, the distal end of the stretch-valve tube 2520 can slide within the inflation lumen 2422 in a proximal direction.

Reference is made to the flow chart of FIG. 40 to explain one exemplary embodiment of a process for making a catheter according to the embodiment of FIGS. 27 to 29.

The catheter starts, in Step 4010 with a dual lumen extrusion of latex. This extrusion, therefore, defines the annular inner lumen wall 2710 with the drainage lumen 2712 and, at one or more circumferential longitudinal extents about the inner lumen wall 2710, an inflation lumen wall 2720 with the inflation lumen 2722. The dual lumen, therefore, already includes both the drainage lumen 2712 and the inflation lumen 2722. Both lumen 2712, 2722, however, are extruded without obstruction and without radial ports. Therefore, in order to have the inflation port 2724, a radial hole needs to be created between the outside surface of the extrusion and the inflation lumen.

In Step 4012, the balloon inflation port 2724 is made to fluidically connect the environment of the extrusion to the inflation lumen 2722.

Different from the other exemplary embodiments described, a distal port 2760 is created in Step 4014 before, after, or at the same time as the balloon inflation port 2724. The distal port 2760 connects the environment to the interior of the drain lumen 2712. In an exemplary embodiment, the distal port 2760 is proximal of the balloon inflation port 2724.

Sealing off of the distal end of the inflation lumen 2722 can be performed in Step 4016 by inserting or creating a plug 2726 therein or the sealing can occur simultaneously with the creation of the outer wall 2740 below.

In Step 4018, a balloon sleeve 2730 is placed about the inflation port 2724 and the distal port 2760 and is fixed to the exterior of the inflation lumen wall 2720 at both ends to define a fluid-tight balloon interior 2200 therebetween. As such, inflation of the balloon 2810 can occur through the inflation lumen 2722. For example, the tube 2730 making up the inner balloon wall is slid over the distal end of the dual-lumen extrusion to cover the inflation port 2724 and is fluid-tightly sealed to the inner multi-lumen extrusion at both ends of the tube but not in the intermediate portion. This tube can be made of latex as well and, therefore, can be secured to the latex multi-lumen extrusion in any known way to bond latex in a fluid-tight manner.

The stretch valve is now completed. A proximal port 2750 is formed through the inflation lumen wall 2020 in Step 4020. Then, in Step 4022, the stretch-valve tube 2820 is inserted through either one of the proximal or distal ports 2750, 2760 such that the proximal port 2750 overlaps at least a portion of the proximal end of the stretch-valve tube 2820 and the distal port 2760 overlaps at least a portion of the distal end of the stretch-valve tube 2820. In this manner, two portions of the outer surface of the proximal end of the stretch-valve tube 2820 at the proximal and distal ports 2750, 2760 are exposed to the environment but there is no fluid communication with the inflation lumen 2722 and the proximal or distal ports 2750, 2760. Alternatively, Steps 4022 can occur before 4018 to insert the stretch-valve tube 2820 before the balloon sleeve 2730 is placed and fixed. In such a case, the creation of the proximal port 2750 can occur before, after, or at the same time as creating the distal port 2760 and the balloon inflation port

2724, in which embodiment, all three ports 2724, 2750, 2760 can be created at the same time.

In Step 4024, the entire sub-assembly is covered with the outer wall 2740. For example, the entire sub-assembly is dipped into latex in its liquid form to create the outer wall 2740. In the alternative embodiment where a distal inflation lumen plug is not used, the latex can be allowed to enter at least a portion of the distal end of the inflation lumen 2722 but not so far as to block the inflation port 2724. When the latex cures, the balloon 2810 is fluid tight and can only be fluidically connected to the environment through the proximal-most opening of the inflation port, which is fluidically connected to the inflation lumen 2722. In this process, the inner wall 2710, the inflation lumen wall 2720, the plug 2726, the balloon wall 2730, and the outer wall 2740 are all made of the same latex material and, therefore, together, form a very securely water-tight balloon 2810.

In previous embodiments, the proximal port 2750 pierced the outer wall 2740. In this exemplary embodiment, however, there is no need to do so. Here, the proximal port 2750 can be filled with material of the outer wall 2740 itself to fix the proximal end of the stretch-valve tube 2820 to at least one of the outer wall 2740 and the inflation lumen wall 2020. When the latex cures, the connection at the proximal port 2750 is fluid tight and no longer permits fluidic connection to the environment therethrough. In this process, therefore, the filled proximal port 2750, the inflation lumen wall 2720, and the outer wall 2740 are all made of the same latex material and, therefore, together, form a very securely water-tight connection. In an alternative exemplary embodiment, an adhesive can be used to bond the proximal end of the stretch-valve tube 2820 to the inflation lumen wall 2720.

In such a configuration, therefore, any proximal movement of the catheter 2700 at or proximal of the proximal port 2750 will also move the stretch-valve tube 2820 proximally; in other words, the distal end of the stretch-valve tube 2820 can slide within the inflation lumen 2722 in a proximal direction.

Reference is made to the flow chart of FIG. 41 to explain one exemplary embodiment of a process for making a catheter according to the embodiment of FIGS. 37 and 38.

The catheter starts, in Step 4110 with a dual lumen extrusion of latex. This extrusion, therefore, defines the annular inner lumen wall 3710, 3810 with the drainage lumen 3712, 3812 and, at one or more circumferential longitudinal extents about the inner lumen wall 3710, 3810, an inflation lumen wall 3720, 3820 with the inflation lumen 3722, 3822. The dual lumen, therefore, already includes both the drainage lumen 2712, 2812 and the inflation lumen 2722, 2822. Both lumen 2712, 2722, 2812, 2822, however, are extruded without obstruction and without radial ports. Therefore, in order to have the inflation port 3724, 3824, a radial hole needs to be created between the outside surface of the extrusion and the inflation lumen.

In Step 4112, the balloon inflation port 3724, 3824 is made to fluidically connect the environment of the extrusion to the inflation lumen 3722, 3822.

Different from the other exemplary embodiments described, with regard to the embodiment of FIG. 37, the deflation port 3760 is created in Step 4114 before, after, or at the same time as the balloon inflation port 3724. The deflation port 3760 connects the interior of the balloon 3742 to the interior of the drain lumen 3712. In an exemplary embodiment, the deflation port 3760 is proximal of the balloon inflation port 3724 but can be at or distal thereof.

Different from the other exemplary embodiments described, with regard to the embodiment of FIG. 38, the drainage ports 3860 and 3862 are created in Step 4114 before,

after, or at the same time as the balloon inflation port 3824. The drainage port 3860 connects the interior of the balloon 3842 to the interior of the drain lumen 2712 and the drainage port 3862 connects the interior of the inflation lumen 3822 to the interior of the drain lumen 2712. In an exemplary embodiment, the drainage ports 3860, 3862 are aligned with the balloon inflation port 3824 but they can be distal or proximal thereof. When aligned, a single through-hole can be made through the entire catheter, penetrating both the inflation and drainage channels 3712, 3722, 3812, 3822 and both walls 3710, 3720, 3810, 3820 of the catheter. Alternatively, the drainage ports 3860, 3862 can be spaced from one another with either one or neither aligned with the inflation port 3824.

In Step 4116, a fixation point 3732, 3832 is established at the outer wall 3710, 3810. At this fixation point 3732, 3832 are the measures for fixing the stretch-valve tube 3730, 3830 inside the drainage lumen 3712, 3812. The fixation point 3732, 3832 can be placed anywhere proximal of the drainage ports 3760, 3860, 3862. The fixation point 3732, 3832 is not aligned circumferentially with the inflation port 3724, 3824 as shown in FIGS. 37 and 38. In the exemplary embodiment shown, the fixation point 3732, 3832 is still within the proximal end of the balloon 3742, 3842 but it can equally be further proximal of the balloon 3742, 3842 to any point proximal within the drainage lumen 3712, 3812.

Sealing off of the distal end of the inflation lumen 3722, 3822 can be performed in Step 4118 by inserting or creating a plug 3736, 3836 therein or the sealing can occur before forming the fixation ports or just before or simultaneously with the creation of the outer wall 3740, 3840 below in Step 4124.

In Step 4120, the stretch-valve tube 3730, 3830 is inserted into the drainage lumen 3712, 3812 and aligned so that the stretch-valve tube 3730, 3830 covers all drainage ports 3760, 3860, 3862 and all of the fixation through-holes 3732, 3832. The distal end of the stretch-valve tube 3730, 3830 is positioned at the distal distance S desired for operation of the stretch valve. For example, the distance can be up to 1 mm, up to 2 mm, up to 3 mm and up to even 1 or 2 cm. The distance S can also be dependent on the amount of stretch at the proximal end of the catheter as the displacement of the stretch-valve tube is proportional to the stretch of the catheter. For example, if the catheter is 500 mm long and is pulled 20%, then it will be 600 mm long (a 100 mm stretch). A 10 mm or longer stretch-valve tube made from a stiff material, such as metal (e.g., stainless steel, titanium, etc.) polycarbonate, polyimide, polyamide, polyurethane (Shore 55D-75D), and the like, located near the balloon of the catheter has its proximal end glued to the inside of the inflation or drainage lumen. When this catheter is stretched than 20%, then the distal tip of a 10 mm stretch valve will move 2 mm in the proximal direction. Accordingly, if the drainage port(s) is placed 2 mm proximal to the distal end of the stretch-valve tube (here, S=2 mm), it will remain sealed by the stretch-valve tube at a stretch of about 20%. But, when the catheter is pulled slightly more than 20% (or 2 mm), the drainage port will unseal and the inflation fluid within the balloon will discharge out the drainage port. As catheters vary among manufacturers, calibration of the percent stretch to the force required to stretch the catheter can be done for each different type of catheter. This force is defined in engineering terms as a modulus of the catheter and is a function of the modulus of the material and the effective wall thickness of the catheter. Low modulus materials and catheters will stretch more than high modulus materials and catheters when exposed to the same force. Exemplary catheters are those made from latex rubber or silicone rubber. Silicone rubber generally has a higher modu-

lus than latex and, therefore, more force is required to stretch the catheter sufficiently to discharge the pressure within the balloon. Those of skill in the art, therefore, will understand that different stretch valves lengths can be provided to dump the balloon pressure as a function of a tug-force on the different catheters made from the different materials and having different wall thicknesses. Accordingly, even though the stretch-valve tube distances are given, they are exemplary and can change for different catheters having different materials/thicknesses. As such, these exemplary distances for actuating the stretch-valve tube applies to all embodiments described herein but are not limited thereto.

If the fixation through-holes **3732**, **3832** are within the inflation expanse of the balloon sleeve (as shown), then an adhesive can be used within the fixation through-holes **3732**, **3832** to fix the proximal end of the stretch-valve tube **3730**, **3830** thereat before attachment of the balloon sleeve. If the fixation through-holes **3732**, **3832** are within the expanse of the balloon sleeve but only overlap at the fixed proximal end of the balloon sleeve (not illustrated), then the same adhesive that fixes the proximal end of the balloon sleeve can be used within the fixation through-holes **3732**, **3832** to fix the proximal end of the stretch-valve tube **3730**, **3830** thereat. Finally, if the fixation through-holes **3732**, **3832** are outside the expanse of the balloon sleeve proximally, then an adhesive or the same material that creates the outer wall **3740**, **3840** (see below) can be used within the fixation through-holes **3732**, **3832** to fix the proximal end of the stretch-valve tube **3730**, **3830**.

In Step **4122**, the balloon sleeve is placed about the inflation port **3724**, **3824** and the fixation through-holes **3732**, **3832** (if the fixation through-holes **3732**, **3832** are within the expanse of the balloon sleeve) and the balloon sleeve is fixed to the exterior of the inner and inflation lumen walls **3710**, **3720**, **3810**, **3820** at both ends to define a fluid-tight balloon interior therebetween. As such, inflation of the balloon **3742**, **3842** can occur through the inflation lumen **3722**, **3822**. For example, the balloon sleeve making up the inner wall of the balloon **3742**, **3842** is slid over the distal end of the dual-lumen extrusion to cover at least the inflation port **3724**, **3824** and is fluid-tightly sealed to the inner multi-lumen extrusion at both ends of the balloon sleeve but not in the intermediate portion. The balloon sleeve can be made of latex as well and, therefore, can be secured to the latex multi-lumen extrusion in any known way to bond latex in a fluid-tight manner.

In Step **4124**, the entire sub-assembly is covered with the outer wall **3740**, **3840**. For example, the entire sub-assembly is dipped into latex in its liquid form to create the outer wall **3740**, **3840**. In the alternative embodiment where a distal inflation lumen plug **3736**, **3836** is not used, the latex can be allowed to enter at least a portion of the distal end of the inflation lumen **3722**, **3822** but not so far as to block the inflation port **3724**, **3824**. When the latex cures, the balloon **3742**, **3842** is fluid tight and can only be fluidically connected to the environment through the proximal-most opening of the inflation port, which is fluidically connected to the inflation lumen **3722**, **3822**. In this process, the inner wall **3710**, **3810**, the inflation lumen wall **3720**, **3820**, the plug **3736**, **3836**, the balloon wall, and the outer wall **3740**, **3840** are all made of the same latex material and, therefore, together, form a very securely water-tight balloon **3742**, **3842**.

In such a configuration, therefore, any proximal movement of the catheter **3700**, **3800** at or proximal of the proximal anchor **3732**, **3832** will also move the stretch-valve tube **3730**, **3830** proximally; in other words, the distal end of the stretch-valve tube **3730**, **3830** can slide within the inflation lumen **3722**, **3822** in a proximal direction.

The steps outlined above in the exemplary embodiments need not be done in the order described or illustrated. Any of these steps can occur in any order to create the catheter according to the various exemplary embodiments.

FIGS. **42** and **43** illustrate the balloon portion of other exemplary embodiments of the inventive catheter **4200**, **4300**, again with the balloon **3842** in a partially inflated state. In these exemplary embodiments, most of the features are the same as the catheter **3800** shown in FIG. **38**, as well as in the other exemplary embodiments of the safety catheters described herein. What is different in FIGS. **42** and **43** is how the stretch valve operates and, therefore, the similar features use the same reference numerals as in FIG. **38**. Different features, however, use new reference numerals. Thus, description of the similar features is not repeated below and is, instead, incorporated herein by reference from the above-mentioned exemplary embodiments.

In the catheters **4200**, **4300**, the annular inner lumen wall **4210**, **4310** defines therein a drainage lumen **4212**, **4312**. In this exemplary embodiment, a hollow, stretch-valve tube **3830** is disposed in the drainage lumen **4212**, **4312** to not hinder drainage of the fluid to be drained (e.g., urine). While the diameter of the stretch-valve tube **3830** can be any size that accommodates unhindered fluid flow through the drainage lumen **4212**, **4312**, one exemplary inner diameter of the stretch-valve tube **3830** is substantially equal to the diameter of the drainage lumen **4212**, **4312** and the outer diameter of the stretch-valve tube **3830** is just slightly larger than the diameter of the drainage lumen **4212**, **4312** (e.g., the wall thickness of the tube can be between 0.07 mm and 0.7 mm). (In any embodiment of the stretch-valve tube mentioned herein, the outer diameter can be equal to or less than the diameter of the drainage lumen.)

The proximal end of the stretch-valve tube **3830** in this exemplary embodiment is proximal of a proximal end of a deflation port **3860**. The distal end of the stretch-valve tube **3830** is not distal of the distal end of the balloon **3842** so that the balloon **3842** can be deflated; the distal end can be anywhere between the two ends of the balloon **3842** but is shown in an intermediate position in FIGS. **42** and **43**. The distal end of the stretch-valve tube **3830** is at a distance **S** distal of the deflation port **3860** and selection of this distance **S** is dependent upon the amount of stretch required to actuate the stretch-valve of the inventive catheter **4200**, **4300** as described herein.

In the exemplary embodiments of FIGS. **38**, **42** and **43**, the longitudinal length of the deflation port **3860** is shown as less than one half of the longitudinal length of the stretch-valve tube **3830**. The drainage port **3860** is formed through the inner lumen wall **3810** and the stretch-valve tube **3830** is positioned to overlap at least the drainage port **3860**. In this manner, a portion of the outer surface of the proximal end of the stretch-valve tube **3830** closes off the drainage port **3860** to prevent fluid communication from the balloon **3842** to the drainage lumen **4212**, **4312** through the drainage port **3860**. A second drainage port **3862** is provided in the inner lumen wall **3810** aligned with the drainage port **3860**, and both drainage ports **3860**, **3862** are aligned with the inflation port **3824**. As such, when the stretch-valve tube **3830** moves proximally to uncover the drainage ports **3860**, **3862**, inflation fluid **3802** from inside the balloon **3842** exits from both the inflation port **3824** and the drainage port **3860**.

To secure the stretch-valve tube **3830** in the catheter **4200**, **4300**, a proximal anchor **4232**, **4332** is disposed in the drainage lumen **4212** away from the deflation ports **3860**, **3862**, here proximally at a distance **E** in FIG. **42** and at a longer distance **F** in FIG. **43**. The distances shown are not the only

sizes for the stretch-valve tube **3830** and can be shorter or longer, the latter extending well into the drainage lumen **4212**, **4312** proximally even further than shown in FIG. **43**. The proximal anchor **3832** can be any size or shape that accommodates unhindered fluid flow through the drainage lumen **4212**, **4312**, one exemplary inner diameter of the hollow anchor **3832** being a tube or ring substantially equal to the diameter of the drainage lumen **4212** with an outer diameter just slightly larger than the diameter of the drainage lumen **4212** (e.g., the thickness of the tube can be between 0.07 mm and 0.7 mm). The proximal anchor **3832** can be a barb or other mechanical fixation device as well, whether integral or connected to the stretch-valve tube **3830**. The longitudinal length of this anchor **3832** can be as long as desired but enough to longitudinally fixedly secure the proximal end of the stretch-valve tube **3830** within the drainage lumen **4212** when installed in place. The anchor **3832** in this exemplary embodiment is at the proximal end of the balloon **3842** as shown in FIG. **42** but it can be further inside the balloon **3842** (i.e., distal with regard to FIG. **42**) or entirely proximal of the balloon **3842** as shown in FIG. **43**. The further proximal that the anchor **3832** is connected within the drainage lumen **4212**, **4312**, the greater the distance of stretching material is disposed between the anchor **3832** and the drainage ports **3860**, **3862**, thereby enhancing the ability of the safety catheter to stretch and activate the stretch-valve.

In such a configuration, therefore, any proximal movement of the catheter **4200**, **4300** at or proximal to the drainage ports **3860**, **3862** will also move the stretch-valve tube **3830** proximally; in other words, the distal end of the stretch-valve tube **3830** can slide within the drainage lumen **4212** in a proximal direction. When the proximal end of the catheter **4200**, **4300** is pulled to a force that is no greater than just before injury would occur to the urethrovaginal junction or the urethra if the catheter **4200**, **4300** was still inflated when the force was imparted, the force will cause the distal end of the stretch-valve tube **3830** to slide proximally and translate and open the drainage ports **3860**, **3862** at a deflation point, e.g., with a pulling force in a range of 1 to 15 pounds. In another exemplary embodiment, the range of force required to meet the deflation point is between 1 and 5 pounds, in particular, between 1.5 and 2 pounds.

When the deflation point of the stretch-valve tube **3830** starts, the interior of the balloon **3842** becomes fluidically connected directly into the drainage lumen **4212**, **4312** (which is open to the interior of the bladder **2020** and to the non-illustrated, proximal drain bag) and, due to the fact that the bladder is relatively unpressurized as compared to the balloon **3842**, all internal pressure is released from the balloon **3842** to eject the inflating fluid **3802** directly into the drainage lumen **4212**, **4312**, thereby causing the balloon **3842** to deflate rapidly.

There exists the possibility that the distal end of stretch-valve tube **3830** might not slide or will slide with friction when the proximal end of the catheter **4200**, **4300** is pulled to a force that is enough to reach the desired deflation point (and no greater than just before injury would occur). To prevent such a situation from occurring, it is desirable to enhance the stretchability of the inner lumen wall **4210** distal of the anchor **3832** and, in particular, the extent E between the drainage ports **3860**, **3862** and the anchor **3832**. Because the material of the catheters described herein is naturally stretchable, there are various ways to make the extent E stretch more than other portions of the catheter, in particular, the portion proximal of the anchor **3832**. One way to increase the stretchability is to score the outside or inside of the material comprising the extent E with small cuts, notches, scratches, or other inten-

tionally formed defects. Another way to make the extent E more stretchable than at least the portion proximal of the anchor **3832** is to grind down the exterior or interior of the extent E. A further way to make the extent E more stretchable is to chemically treat the material comprising the extent E. Yet another way to make the extent E more stretchable is to treat the material comprising the extent E with a local change in temperature, such as heating the extent E.

An altogether different way is to use different materials in the catheter **4200**, **4300**. In one exemplary embodiment, at least a portion of the extent E is replaced with another elastomeric material different from the remainder of the catheter, the other elastomeric material being more elastic than at least the portion of the catheter proximal of the anchor **3832**. In another exemplary embodiment, the portion proximal of the anchor **3832** is made of an elastomeric material that is less elastic than the extent E.

FIG. **43** shows the stretch-valve tube **4330** significantly longer than the other stretch-valve tubes and attached by the anchor **4332** to the inner lumen wall **4310** even further proximally than the other stretch-valve tubes. By making the stretch-valve tube **4330** longer, the extent E can be increased, thereby making stretch of the portion just distal of the anchor **3832** easier and insuring activation of the stretch valve. Any of the exemplary embodiments of the stretch-valve tube can have a different length than illustrated and/or described.

Even though the exemplary embodiments **4200**, **4300** are shown herein with reference to FIG. **38**, they are not limited thereto and can be applied to each of the other exemplary embodiments described herein as well. Further, the stretch enhancement feature can be added to the outer wall instead of or in addition to the inner lumen wall. If the stretch enhancement **4270**, **4370** is included in the production of any of the herein-mentioned catheters, then another manufacturing step will be needed. As such, a stretch-enhancement creation step will be added, for example, in the flow chart of FIG. **39** anywhere after step **3910**, in the flow chart of FIG. **40** anywhere after step **4010**, and in the flow chart of FIG. **41** anywhere after step **4110**.

The catheters **200**, **300**, **1000**, **1600**, **2100**, **2400**, **2700**, **3300**, **3400**, **3500**, **3600**, **3700**, **3800**, **4200**, **4300** according to the invention can be used in vascular applications. It is known that every vessel has a tearing pressure. Balloons are used in coronary arteries, for example. If a coronary artery balloon were to burst, there would be less damage if the burst was controlled according to the invention. The same is true for a renal or iliac blood vessel. In such situations, the breakaway catheter improves upon existing catheters by making them safer. From the urinary standpoint, the breakaway balloon will not only prevent injury, but will also be a signal to the technician that he/she needs to obtain the assistance of a physician or urologist with respect to inserting the catheter.

The invention claimed is:

1. A safety catheter, comprising:

- a flexible, multi-lumen shaft having an outer diameter, a distal tip, a proximal shaft portion, and a proximal catheter end with a proximal drain end and a proximal inflation end, the multi-lumen shaft defining:
  - a drain lumen extending through the shaft and operable to drain fluid adjacent the distal tip therethrough and out the proximal drain end;
  - a distal hollow balloon portion defining a balloon interior and having at least one inflation port fluidically connected to the balloon interior, the balloon portion operable to be inflated outwardly through the at least one inflation port to a diameter greater than the outer diameter of the shaft;

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- at least one inflation lumen parallel to the drain lumen and fluidically connected to the at least one inflation port, the at least one inflation lumen operable to inflate the balloon interior with an inflation fluid; and  
 a drainage port fluidically connecting at least one of the balloon interior and the at least one inflation lumen to the drain lumen;  
 a hollow stretch valve:  
   coaxially disposed in the drain lumen and operable to permit fluid to pass therethrough;  
   positioned in the drain lumen to prevent fluid from passing through the drainage port in a steady state;  
   having a distal valve end and a proximal valve end;  
   having a fixed portion at the proximal valve end fixedly connected within the drain lumen; and  
   having a sliding portion slidably disposed within the drain lumen at the distal valve end such that, in a stretched state when the proximal catheter end is stretched, the sliding portion slides within the drain lumen to permit the inflation fluid to pass through the drainage port; and  
 the multi-lumen shaft having an extent distal of the connection of the fixed portion that is relatively more stretchable than at least a portion of the multi-lumen shaft proximal of the extent.
2. The safety catheter according to claim 1, wherein the stretch valve has the stretched state at a pull force of between approximately 1 pound and approximately 15 pounds applied to the proximal shaft portion.
  3. The safety catheter according to claim 1, wherein the stretch valve has the stretched state at a pull force of between approximately 1.5 pounds and approximately 2 pounds applied to the proximal shaft portion.
  4. The safety catheter according to claim 1, wherein, when the balloon portion is inflated with a fluid and a pull force of greater than approximately 15 pounds is applied to the proximal shaft portion, the stretch valve meets the stretched state and thereby deflates the inflated hollow balloon portion.
  5. The safety catheter according to claim 1, wherein, when the balloon portion is inflated with a fluid and a pull force of greater than approximately 5 pounds is applied to the proximal shaft portion, the stretch valve meets the stretched state and thereby deflates the inflated hollow balloon portion.
  6. The safety catheter according to claim 1, wherein, when the balloon portion is inflated with a fluid and a pull force of greater than approximately 2 pounds is applied to the proximal shaft portion, the stretch valve meets the stretched state and thereby deflates the inflated hollow balloon portion.
  7. The safety catheter according to claim 1, wherein the stretch valve has the stretched state at a pull force of between approximately 1 pound and approximately 5 pounds applied to the proximal shaft portion.
  8. The safety catheter according to claim 1, wherein the drainage port is a plurality of drainage ports fluidically connecting at least one of the balloon interior and the at least one inflation lumen to the drain lumen.
  9. The safety catheter according to claim 1, wherein:  
   the balloon has a proximal end; and  
   the fixed portion of the hollow stretch valve is proximal of the proximal end of the balloon.
  10. A safety catheter, comprising:  
   a flexible, multi-lumen shaft having an outer diameter, a distal tip, a proximal shaft portion, and a proximal catheter end with a drain end and an inflation end, the multi-lumen shaft defining:

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- a drain lumen extending through the shaft and operable to drain fluid adjacent the distal tip therethrough and out the drain end;  
 a distal hollow balloon portion defining a balloon interior and having at least one inflation port fluidically connected to the balloon interior, the balloon portion operable to be inflated outwardly through the at least one inflation port to a diameter greater than the outer diameter of the shaft;  
 at least one inflation lumen parallel to the drain lumen and fluidically connected to the at least one inflation port, the at least one inflation lumen operable to inflate the balloon interior with an inflation fluid; and  
 a drainage port fluidically connecting the balloon interior to the drain lumen;  
 a hollow stretch valve:  
   coaxially disposed in the drain lumen and operable to permit fluid to pass therethrough;  
   positioned in the drain lumen to prevent fluid from passing through the drainage port in a steady state;  
   having a distal valve end and a proximal valve end;  
   having a fixed portion at the distal valve end fixedly connected within the drain lumen; and  
   having a sliding portion slidably disposed within the drain lumen at the proximal valve end such that, in a stretched state when the proximal catheter end is stretched, the sliding portion slides within the drain lumen to permit the inflation fluid to pass through the drainage port; and  
 the multi-lumen shaft having an extent distal of the connection of the fixed portion that is relatively more stretchable than at least a portion of the multi-lumen shaft proximal of the extent.
11. The safety catheter according to claim 10, wherein the stretch valve has the stretched state at a pull force of between approximately 1 pound and approximately 15 pounds applied to the proximal shaft portion.
  12. The safety catheter according to claim 10, wherein the stretch valve has the stretched state at a pull force of between approximately 1 pound and approximately 5 pounds applied to the proximal shaft portion.
  13. The safety catheter according to claim 10, wherein the stretch valve has the stretched state at a pull force of between approximately 1.5 pounds and approximately 2 pounds applied to the proximal shaft portion.
  14. The safety catheter according to claim 10, wherein, when the balloon portion is inflated with a fluid and a pull force of greater than approximately 15 pounds is applied to the proximal shaft portion, the stretch valve meets the stretched state and thereby deflates the inflated hollow balloon portion.
  15. The safety catheter according to claim 10, wherein, when the balloon portion is inflated with a fluid and a pull force of greater than approximately 5 pounds is applied to the proximal shaft portion, the stretch valve meets the stretched state and thereby deflates the inflated hollow balloon portion.
  16. The safety catheter according to claim 10, wherein, when the balloon portion is inflated with a fluid and a pull force of greater than approximately 2 pounds is applied to the proximal shaft portion, the stretch valve meets the stretched state and thereby deflates the inflated hollow balloon portion.
  17. The safety catheter according to claim 10, wherein the drainage port fluidically connects the balloon interior and the at least one inflation lumen to the drain lumen.

18. The safety catheter according to claim 10, wherein:  
the drainage port is a plurality of drainage ports each flu-  
idically connecting the balloon interior to the drain  
lumen; and

the hollow stretch valve:

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is positioned in the drain lumen to prevent fluid from  
passing through the plurality of drainage ports in the  
steady state; and

has the sliding portion slidably disposed within the drain  
lumen such that, in the stretched state when the proxi- 10  
mal catheter end is stretched, the sliding portion slides  
within the drain lumen to permit the inflation fluid to  
pass through the plurality of drainage ports.

19. The safety catheter according to claim 10, wherein:

the balloon has a proximal end; and

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the fixed portion of the hollow stretch valve is proximal of  
the proximal end of the balloon.

\* \* \* \* \*